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U.S. Army Environmental Hygiene Agency

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APPLICATION OF THE PROPOSED DRAFT AMERICAN NATIONAL STANDARD METHOD FOR EVALUATING THE EFFECTIVENESS OF HEARING CONSERVATION PROGRAMS

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Application of the Proposed Draft American National Standard Method for Evaluating the Effectiveness of Hearing Conservation Programs

BY

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ABSTRACT

This study describes the application of the Draft American National Standard ANSI S12.13-1991 (DANS) method for evaluating the effectiveness of hearing conservation programs (HCPs) to audiometric data collected from civilian workers in the U.S. Army during 1968-1992. The DANS method was applied to two groups of workers: those who met the DANS criteria for at least four consecutive tests (Cohort-A4), and those having at least eight consecutive tests (Cohort-A8). While 1.5% (1,193/82,195) of the original population qualified to enter Cohort-A4, only 0.3% (260/82,195) qualified for Cohort-A8. Within each group, the HCP for civilian workers in the Army was rated using four different procedures as applicable (i.e., the Percent Worse Sequential, Percent Better or Worse Sequential, Standard Deviation for individual test frequencies, and Standard Deviation for averaged test frequencies). Where possible, data for men and women were analyzed separately. Each of the four procedures rated the HCP as marginal *(scale: acceptable, marginal, unacceptable)* for both men and women. The implications of evaluating the effectiveness of an HCP on the basis of a very small proportion of the study population are discussed.

INTRODUCTION

Even though loss of hearing due to noise exposure has been reported for centuries, noise-induced hearing loss is still one of the leading causes of preventable work-related conditions in the United States.[1,2] The National Institute for Occupational Safety and Health (NIOSH) estimates that from 8.1 to 12.3 million workers are exposed to levels of noise greater than 85 dBA.[3]

In the United States, the armed forces were early leaders in developing regulations to control workers' exposure to noise. By the mid-1950's, the U.S. Air Force, Army and Navy had issued directives designed to prevent noise-induced hearing loss.[4] The federal government followed, issuing the first federal regulation governing noise exposure in 1969. This Department of Labor noise regulation was originally included under the Walsh-Healey Public Contracts Act and applied only to employers contracting with the government. With the enactment of the Occupational Safety and Health (OSH) Act of 1970, this regulation became applicable to all employers covered by the OSH Act. All Department of Defense (DOD) civilian employees came under the Occupational Safety and Health Administration (OSHA) regulations following the enactment of Executive Order 11612 in 1971.[5] Today, in general industry, Hearing Conservation Programs (HCPs) are required in any workplace where employees are exposed to noise levels that equal or exceed an 8-hour time-weighted average sound level of 85 decibels measured on the A-weighted scale.[6]

While federal and DoD regulations have mandated HCPs, the financial

realities of large disability and workers' compensation claims within the Department of the Army (DA) and the Office of Workers' Compensation Programs (OWCP), also encouraged development of programs to reduce noise-induced hearing loss. The OWCP costs for U.S. federal agencies in fiscal year 1992 totaled $27,964,724 for 5651 hearing loss claims. For all government agencies, 2% of all claims and slightly less than 2% of all compensation dollars are for hearing loss.[7] In 1992, DA paid $5,095,970 in compensation costs for 864 cases of hearing loss. The cost for hearing loss compensation represents 3% of all DA compensation dollars spent, and the hearing loss cases make up slightly less than 4% of all workers' compensation cases.[8]

In view of the enormous magnitude of this problem, it is of utmost importance that the U.S. Army's HCP is comprehensive and effective. Overall, any HCP is designed to prevent noise-induced hearing loss through noise control, worker training, and monitoring of noise and worker hearing. A comprehensive HCP has seven basic elements: noise exposure surveys, engineering controls, audiometric evaluations, worker education and training, use of hearing protection devices, record keeping, and evaluation of overall program effectiveness.[9] Of these seven elements, the program element often difficult to implement is evaluation of the overall program effectiveness. Periodic evaluations of the programs are necessary not only to assess compliance with appropriate regulations but also to assess the audiometric data for the individual worker and the workers, as a group.

In this document we will describe the use of a specific audiometric data

base analysis (ADBA) method to evaluate the overall program effectiveness of the U.S. Army HCP for civilian workers within the U.S. Army. This analysis method is proposed in American National Standards Institute (ANSI) S12.13 Draft Standard[10] and is the product of the ANSI Working Group S12/WG13. The purpose of the draft standard is:

> "to define objective procedures for evaluating HCP effectiveness in preventing occupational noise-induced hearing loss in a noise-exposed population through ADBA, the evaluation of certain variability characteristics of the serial audiometric data for the noise-exposed population as a whole, or for selected subgroups."

The ADBA developed by the ANSI working group is applicable to group audiometric data only and requires results of serial monitoring audiometry for the noise-exposed workers in the HCP. This method differs from the traditional approach and does not eliminate the need for reviewing individual audiograms for specific hearing threshold shifts required by OSHA.

The goal of ADBA is to enhance prevention of noise-induced hearing loss through systematically assessing the effectiveness of hearing conservation programs. According to the DANS, the objective data obtained through ADBA can identify potential problem areas in the HCP before employees develop significant hearing loss and can be used as a guide to management decisions on the needs for change in the HCP, to motivate workers and supervisors and to increase the awareness of the importance of the HCP. The ANSI working group believes that evaluating HCPs with ADBA will provide tangible benefits for both

the noise-exposed employee and the employer. This report describes the application of the Draft American National Standard ANSI S12.13-1991 (DANS) method for evaluating the effectiveness of HCPs to a large set of audiometric data collected from civilian workers in the US Army during 1976-1992.

METHODS

The Study Population

The study population consisted of 82,195 civilian workers representing 258,472 audiograms. Workers were enrolled in the Army-wide HCP at a number of different installations throughout the country if they were exposed to: a) steady state noise of 85 dBA or greater in the audible range, up to 16000 Hz, regardless of duration; b) impulse noise of 140 peak decibels (dBP) or greater; c) airborne high frequency or ultrasonic noise, regardless of duration, in any of the one-third octave bands exceeding the corresponding value listed.[11] In this paper, workers who met any one of the above criterion were considered as exposed to industrial noise.

All personnel working in noise-hazardous areas were required to have hearing protection devices with them at all times. Hearing protection devices include earplugs, noise muffs, ear canal caps, noise-attenuating helmets, or a combination of these. They were provided at no charge to all personnel working in noise-hazardous areas. Personnel were permitted to choose the type of protection devices they desire, unless their selection was medically contraindicated or inappropriate for a particular noise-hazardous area. The type of protection (single or combination protectors) required at different levels of noise, and the maximum allowable duration of exposure have been specified elsewhere [12].

Audiometric data have been used to identify individuals who were highly

susceptible to noise-induced hearing loss, and to evaluate the effectiveness of the hearing conservation program. All noise-exposed civilian personnel were required to receive reference, 90-day, annual, and termination audiograms. Reference audiograms for new employees must be performed no later than 30 days after initial exposure to hazardous noise, and termination audiograms should be conducted at least one week prior to the employee's termination.

The Hearing Evaluation Automated Registry System (HEARS) audiometer is the only audiometer authorized for use with the HCP. Audiometric thresholds were validated by conducting annual electroacoustical calibrations, daily audiometric calibration checks, and daily functional checks. Allowable background noise levels for hearing conservation audiometry rooms were required to conform to specifications [13]. Audiometric tests were administered either by a physician, an audiologist, or an audiometric technician who is certified by the Council for Accreditation in Occupational Hearing Conservation (CAOHC) or who has completed the equivalent military training.

Worker education and training was provided by the hearing conservation officer at least annually to all noise-exposed personnel, with documentation of participation and areas covered to include: a) the effects of noise on hearing; b) the purpose, advantages, disadvantages, and attenuation of various types of hearing protectors; c) the selection, fitting, care, and use of hearing protectors; d) the purpose and procedures of audiometric evaluations.

It was the duty of supervisors of noise-hazardous areas to enforce the mandatory use of hearing protectors and ensure that employees report for

scheduled medical examinations. In addition, the hearing conservation officer was expected to conduct unannounced inspections of noise-hazardous areas to ensure compliance with hearing protector requirements. An employee who violates hearing protector requirements or fails to comply with audiometric evaluation procedures may face penalties in accordance with the provisions of AR 690-700[14].

Each installation's HCP was evaluated by the Bio-Acoustics Division of the U.S. Army Environmental Hygiene Agency (USAEHA) and the local hearing conservation officer to assess (a) the completeness and quality of the program's components; (b) the level of program participation, i.e., the proportion of employees who are referred to the HCP, but do not participate in monitoring audiometry; (c) the types of hearing protectors used and earplug fitting procedures; and (d) the audiometric data both for individuals and for groups of noise-exposed employees.

Subject Selection

The Occupational Health Management Information System (OHMIS) at Fort Detrick Data Processing Center provided the audiometric records of 82,195 workers representing 258,472 tests (audiograms) collected during 1968 through 1992.

The subject selection process was conducted in two phases (Phase I: Cohort-A4 and Cohort-A8; Phase II: Cohort-B4). In the first phase of the subject selection process, the DANS method was applied to two cohorts of workers (Table 1): those who met the DANS criteria for at least four consecutive tests (Cohort-A4), and those with at least eight consecutive tests (Cohort-A8). The following procedures were followed for entry into Cohort-A4. First, all workers' reference (form DD2215) and annual audiograms (form DD2216) were selected. Second, for each worker, one audiogram per calendar year was chosen. If, however, more than one test was recorded in a calendar year, the first one was chosen. Third, the interval between consecutive tests of each worker was chosen to be at least 6 months and not more than 18 months. Finally, each selected worker was required to have four or more consecutive tests be conducted in successive calendar years with the first test done in a specific year. (By applying these criteria, we determined that 1982 was the year in which the largest number of workers with at least 4 consecutive tests had their first test, and so for the first phase of the analysis all subjects were required to have their first test in 1982.)

Application of these requirements for entry into Cohort-A4 netted 1,193 subjects. Requirements for entry into Cohort-A8 were the same as Cohort-A4

above except that, for each worker, at least eight (instead of four) consecutive tests were needed in successive calendar years, resulting in 260 subjects. Thus, Cohort-A8 is a subset of Cohort-A4.

In the second phase of the subject selection process, a third cohort (Cohort-B4) was formed from workers who had their first test toward the latter part of the study period. This was done to determine possible changes in program performance over time. A total of 1046 workers who had four consecutive tests during 1988-1991 qualified for entry into Cohort-B4.

Data Analysis

Data analysis was conducted using the DANS method of ADBA which uses procedures based on comparisons of sequential audiograms for measuring year-to-year variability in hearing threshold levels.[15] The procedures used were: Percent Worse Sequential ($\%W_s$), Percent Better or Worse Sequential ($\%BW_s$), Standard Deviation procedure for individual test frequencies ($STDV_s$), and Standard Deviation for averaged test frequencies ($STDVA_s$).

A. Percent Worse Sequential($\%W_s$) Procedure:

The $\%W_s$ procedure computes the proportion of subjects per 100 whose hearing worsened by ≥ 15 dB between two sequential audiograms at test frequencies of 0.5 to 6 kHz in either ear.

In general the formula for the ith comparison ($\%W_{si}$) can be written as:

$$\%Ws_i = \frac{\sum_{j=1}^{N} p_{i,j}}{N} \times 100 \qquad (1)$$

Where,

$\Sigma p_{i,j}$ = Number of persons with difference of hearing threshold levels (HTLs) ≥ 15 dB in ith comparison (ie. between tests i and i+1) at any test frequency (0.5,1,2,3,4, or 6 kHz) in either ear.

$p_{i,j} = 0$ if $=====>$ $L_{f,i+1,j} - L_{f,i,j} < 15$ and $R_{f,i+1,j} - R_{f,i,j} < 15$ for <u>all</u> i <u>and</u> f.

or

$p_{i,j} = 1$ if $=====>$ $L_{f,i+1,j} - L_{f,i,j} \geq 15$ or $R_{f,i+1,j} - R_{f,i,j} \geq 15$

for any i at any f.

$L_{f,i,j}$ = Left ear HTL of the *j*th person's ith test at a frequency of f kHz.

$R_{f,i,j}$ = Right ear HTL of the *j*th person's ith test at a frequency of f kHz.

f = 0.5,1,2,3,4,6 kHz; i = 1, 2, 3 for four consecutive tests; i = 1, 2, 3, 5, 6, 7 for eight consecutive tests; j=1 , 2, ... N; N = Sample size.

B. Percent Better or Worse Sequential ($\%BW_s$) Procedure:

The $\%BW_s$ procedure computes the proportion of subjects per 100 whose hearing changed toward better or worse hearing by ≥ 15 dB between two sequential audiograms at test frequencies of 0.5 to 6 kHz in either ear.

In general, the formula for the ith comparison ($\%BW_s$) can be written as:

$$\%BWs_i = \frac{\sum_{j=1}^{N} q_{i,j}}{N} \times 100 \qquad (2)$$

$\Sigma q_{i,j}$ = Number of persons with difference of HTLs ≥ 15 or ≤ -15 dB in the ith comparison (ie. between tests i and i+1) at any test frequency (0.5,1,2,3,4, or 6 kHz) in either ear.

$q_{i,j} = 0$ if =====> $|L_{f,i+1,j} - L_{f,i,j}| < 15$ and $|R_{f,i+1,j} - R_{f,i,j}| < 15$ for all i = 5, 6, 7 and f.

or

$q_{i,j} = 1$ if =====> $|L_{f,i+1,j} - L_{f,i,j}| \geq 15$ or $|R_{f,i+1,j} - R_{f,i,j}| \geq 15$ for any i = 5, 6, 7 at any f.

Where $L_{f,i,j}$ and $R_{f,i,j}$ are as defined above.

C. Standard Deviation for Individual Test Frequencies ($STDV_s$):

The $STDV_s$ procedure computes the standard deviation of the binaurally averaged HTL differences at separate test frequencies from 0.5 to 6 kHz. The following steps were taken in computing the $STDV_s$ at each frequency:

First, the binaural means of the HTLs were calculated at f kHz for *j*th worker in ith test ($\bar{x}_{f,i,j}$). Second, the differences of the binaural mean HTLs between tests i and i+1 were computed ($X_{f,i,j}$). Third, the standard deviation was computed for the HTL differences across all workers on each sequential test comparison (S_X). Finally, these steps were repeated for all combinations of f and i.

In general the formula can be written as:

$$S_{X_{f,i}} = \sqrt{\frac{\sum_{j=1}^{N} X_{f,i,j}^2 - \frac{(\sum_{j=1}^{N} X_{f,i,j})^2}{N}}{N-1}}$$

Where,

$$X_{f,i,j} = \bar{x}_{f,i+1,j} - \bar{x}_{f,i,j}$$

and $$\bar{x}_{f,i,j} = (L_{f,i,j} + R_{f,i,j})/2$$

Where $L_{f,i,j}$ and $R_{f,i,j}$ are as defined above.

D. Standard Deviation for Averaged Test Frequencies ($STDVA_s$):

The $STDVA_s$ procedure computes the standard deviation of the differences of binaurally average HTL between tests i and *j* at each group of low (0.5,1,2,3 kHz), mid (2,3,4 kHz), and high (3,4,6 kHz) test frequencies. The following steps were taken in computing the $STDVA_s$: First, the binaural means of the HTLs were calculated at each test frequency for each worker on each test ($\bar{x}_{f,i,j}$). Second, the means of the binaural mean HTLs were calculated on each test at each of following combined frequencies: 0.5,1,2,3 kHz; 2,3,4 kHz; and 3,4,6 kHz ($\bar{y}_{g,i,j}$). Third, the differences of the above group HTL means were computed between tests i and i+1 ($Y_{g,i,j}$). Fourth, the standard deviation of these differences was calculated (S_Y). Finally, those steps were repeated for all combinations of g and i.

In general the formula can be written as:

$$S_Y = \sqrt{\frac{\sum_{j=1}^{N} Y_{g,i,j}^2 - \frac{(\sum_{j=1}^{N} Y_{g,i,j})^2}{N}}{N-1}} \qquad (4)$$

Where,

$Y = \bar{y}_{g,i+1,j} - \bar{y}_{g,i,j}$

$g = 1,2,3.$

$\bar{y}_{g,i,j}$ = the *j*th person's mean of the binaural average HTLs for test i and group g of the following combined frequencies: group1 = 0.5,1,2,3 kHz;

group2 = 2,3,4 kHz; and group3 = 3,4,6 kHz.

When g = 1:

$$\bar{y}_{1,i,j} = (\bar{x}_{.5,i,j} + \bar{x}_{1,i,j} + \bar{x}_{2,i,j} + \bar{x}_{3,i,j})/4$$

$$=[(L_{.5,i,j}+R_{.5,i,j})/2 + (L_{1,i,j}+R_{1,i,j})/2 + (L_{2,i,j}+R_{2,i,j})/2 + (L_{3,i,j}+R_{3,i,j})/2]/4$$

($\bar{x}_{1,i,j}$ = *j*th person's mean of binaurally averaged HTLs for test i at 0.5, 1, 2, and 3 kHz).

When g = 2:

$$\bar{y}_{2,i,j} = (\bar{x}_{2,i,j} + \bar{x}_{3,i,j} + \bar{x}_{4,i,j})/3$$

$$= [(L_{2,i,j}+R_{2,i,j})/2 + (L_{3,i,j}+R_{3,i,j})/2 + (L_{4,i,j}+R_{4,i,j})/2]/3$$

($\bar{y}_{2,i,j}$ = *j*th person's mean of binaurally averaged HTLs for test i at 2, 3 and 4 kHz).

When g = 3:

$$\bar{y}_{3,i,j} = (\bar{x}_{3,i,j} + \bar{x}_{4,i,j} + \bar{x}_{6,i,j})/3$$

$$= [(L_{3,i,j}+R_{3,i,j})/2 + (L_{4,i,j}+R_{4,i,j})/2 + (L_{6,i,j}+R_{6,i,j})/2]/3$$

($\bar{y}_{3,i,j}$ = *j*th person's mean of binaurally averaged HTLs for test i at 3, 4 and 6 kHz).

The results from the above procedures were then compared to tables of criterion ranges recommended by the Draft ANSI S12.13-1991[16]. By using these recommended ranges, the effectiveness of the HCP was classified as being "acceptable, marginal, or unacceptable".

Summarizing HCP Ratings: Mean Score Method

The HCP ratings were summarized for each procedure and across

procedures as follows. First, the ratings were scored according to the scale: Unacceptable (U)=0, Marginal (M)=1, Acceptable (A)=2. Second, a mean score was calculated for each procedure and rounded off to the nearest integer. Third, an overall rating of the HCP across different procedures was obtained by taking a mean of the mean scores for all procedures in the cohort and rounding to the nearest integer. For example, using the $\%W_s$ procedure, if the HCP was rated as Marginal (M)=1, Acceptable (A)=2, and Marginal (M)=1, for test comparisons 1-2, 2-3, and 3-4 respectively, the calculated mean score will be 1.3 [i.e., (1+2+1)/3], which when rounded off to the nearest integer becomes 1. Thus, the HCP will be rated as "marginal" by this procedure. In addition, if the HCP received a score of 1.8 (acceptable) by the $STDV_s$ procedure, the overall rating of the HCP across both procedures will be acceptable [i.e., (1.3+1.8)/2=1.6].

This method assigns equal weights to each procedure when summarizing ratings across procedures. Otherwise, the $STDV_s$ procedure will be assigned six times the weight of the $\%W_s$ procedure (N of $\%W_s$ = 3 vs. N of $STDV_s$ = 18), if the individual ratings in each procedure were averaged across procedures.

Summarizing HCP Ratings: Mean Standard Score Method

The HCP ratings for each ADBA procedure were summarized across audiometric frequencies using the mean standard scores as follows. First, the lower and upper limits of the Marginal scores and the raw score values were converted into standard scores. Second, the mean of the standard scores was

calculated for each procedure. Finally, the mean score was assigned a rating of either "acceptable", "marginal", or "unacceptable".

The general formula for calculating mean standard score follows:

$$\textit{Mean Standard Score} = \frac{\sum P_i}{N} \qquad (5)$$

Where,

$(P_i - L_i)/(H_i - L_i) = (C_j - L_j)/(H_j - L_j)$

and,

$P_i = L_i + [(C_j - L_j)(H_i - L_i)]/(H_j - L_j)$

C_j = raw score value from ADBA analysis.

H_j = upper limit of the marginal range in relation to a given raw score.

L_j = lower limit of the marginal range in relation to a given raw score.

H_i = upper limit of the marginal range in relation to a standard score.

L_i = lower limit of the marginal range in relation to a standard score.

In the case where the lower and upper limits of the standard scale are defined as 0 and 1 respectively, the above formula reduces to:

$P_i = (C_j - L_j)/(H_j - L_j)$

RESULTS

Cohort Description

Distribution by Socio-Demographic Factors

At the base line year of 1982, the distribution of age, race, and education by gender for Cohort-A4, Cohort-A8, and Cohort-B4 are displayed in Tables 2, 3, and 4 respectively. For Cohort-A4, the age distributions of males and females were similar, and the mean age at entry was also comparable (i.e., for males 36.8 yrs, for females 36.4 yrs). The largest proportions of males and females were found in the 25-34 age category (42.0% for males and 42.4% for females), with the 35-44 age category being a close second (35.1% for males and 34.3% for females). A similar pattern can be observed for Cohort-A8. Thus, about 70% of the workers who qualified for entry into the study were under the age of 45.

Whereas the racial distribution of Cohort-A4 for whites, blacks, and hispanics, was 76.6%, 11.3%, and 6.2% respectively, the distribution for Cohort-A8 (i.e. members of Cohort-A4 followed for 8 years) was 83.5%, 6.5%, and 1.5%, showing a decline in the proportion of minorities meeting the ADBA criteria over time. In all three cohorts, approximately 55% had attended or completed high school and 30% had attended or completed college.

Comparison of Mean HTLs for Males and Females

We compared the hearing levels of males and females over time at different test frequencies. Figures 1 through 12 show the mean HTLs of Cohort-A4 and Cohort-B4 by test number at different audiometric test frequencies for

both males and females. At least two points are noteworthy from these figures. The first point is that males were generally at higher levels of mean hearing threshold levels over a period of approximately 4 years. The reason for this could be that men are more susceptible to hearing loss, or men are engaged in work environments that are more hazardous to hearing than women. Age differences between men and women could not account for the observed disparities, as the age distribution and the average age at entry were similar for both sexes. The second point observed from these figures is that lower mean hearing threshold levels were generally observed at lower frequencies, and higher mean HTLs were observed at higher frequencies. This is especially true for males where mean HTLs were in the range of 8-13 dB for the lower frequencies (0.5 kHz, 1 kHz, and 2 kHz), and in the range of 20-33 dB for higher frequencies (i.e., 3 kHz, 4 kHz, 6 kHz). In other words, the mean HTLs generally increased with increasing audiometric frequencies.

Mean HTLs by Test Number and Test Frequency

We compared the mean HTLs for different audiometric test frequencies over time for males and females of each of the cohorts (Figures 13-17). In general, higher audiometric test frequencies were associated with higher mean HTLs. This can be more clearly seen for men where the mean HTLs ranged from 20 to 37 dB for high audiometric frequencies (3 kHz, 4 kHz, 6 kHz), while for lower frequencies (0.5, 1, 2 kHz) the mean HTLs ranged from 7 to 13 dB. In addition, a modest but a steady rise in mean HTLs over time was observed at

each frequency for all three cohorts.

We also compared the mean hearing levels of males and females over a range of audiometric test frequencies at different test numbers for all three cohorts (Figures 18-22). In general, a steady increase in mean HTLs was observed with increasing test frequency reaching to a peak at 6 kHz for each test number.

Application of the Draft American National Standard

Cohort-A4 Analysis

In accordance with the requirements of the DANS, Cohort-A4 consisted of workers who had their first test in 1982, and had four consecutive tests. Tables 5 through 10 show results of Audiometric Database Analysis among a total of 1,193 workers (1094 men, 99 women) in Cohort-A4.

Men (N=1094): The $\%W_s$ procedure rated the HCP as "unacceptable" in two of three test comparisons, and "marginal" in one of three test comparisons (Table 5). The mean of the $\%W_s$ values over all test comparisons was 42.9%. This means that approximately 43% of the men in this cohort had worse hearing, indicating an "unacceptable" rating. Similarly, using the "Mean Score Method", the $\%W_s$ procedure rated the HCP as "unacceptable" [i.e., $(0+1+0)/3 = 0.3$].

The $STDV_s$ procedure rated the HCP as "unacceptable" in 7 of 18 (39%) test comparisons, but the same procedure rated the HCP as "acceptable" in 9 of 18 (50%) test comparisons. Overall, using the $STDV_s$ procedure and the "mean scoring method", the HCP was rated as "marginal". Similarly, the $STDVA_s$ procedure rated the HCP as "marginal" (Table 7). Finally, the HCP for men in Cohort-A4 received an overall "marginal" rating across procedures.

Women (N=99): Whereas the $\%W_s$ procedure (Table 8) rated the HCP as "unacceptable" for women (as in men), the $STDV_s$ (Table 9) and the $STDVA_s$ (Table 10) procedures rated it as "marginal". The average of the mean scores of the $\%W_s$ and the standard deviation procedures gave a mean score of 0.8,

indicating an overall rating of "marginal" across procedures. Thus, one can see that while $\%W_s$ procedure rated the HCP in the "unacceptable" range for both men and women, the $STDV_s$ and $STDVA_s$ procedures rated it in the "marginal" range.

Cohort-A8 Analysis

Tables 11 through 14 show results of analysis conducted among a cohort of 260 employees (246 men, 14 women) with eight consecutive tests. The analysis was limited to men only, as the sample size for women was too small for a separate analysis (minimum sample size required: 30). The HCP was rated between "unacceptable" and "marginal" by the $\%W_s$ procedure for all test comparisons (Table 11). The mean $\%W_s$ for all test comparisons was 36.5%, which clearly classifies the HCP in the "unacceptable" range. In contrast, the HCP received a marginal rating using the mean score method where it was 0.5. The %BWs method rated the HCP as "unacceptable" for all test comparisons (Table 12). The $STDV_s$ method gave mixed results where 21 of 36 (58%) test comparisons were rated as acceptable, and 15 of 36 test comparisons were rated as either "unacceptable" or "marginal" (Table 13). The mean score for the $STDV_s$ procedure was 1.3 classifying the HCP in the "marginal" to "acceptable" region. In the $STDVA_s$ procedure (Table 14) the HCP was rated as "acceptable" in 12 of 18 (67%) test comparisons giving a mean score of 1.4, thereby classifying the HCP in the "marginal" range. When these ratings were summarized across all the procedures, the HCP was rated in the "marginal"

range (mean score=0.8) using audiometric test results from men in Cohort-A8.

Cohort-B4 Analysis

A possible change in program performance over time was assessed by forming a third cohort (Cohort-B4) from workers who had their first test toward the latter part of the study period (1988-1991) and comparing it with the earlier cohorts (Cohort-A4, and Cohort-A8). There were a total of 1046 (985 men, 61 women) workers with four consecutive tests who qualified for entry into Cohort-B4. Tables 15 through 20 show results of audiometric database analysis for this cohort.

Men (N=985): For men, the $\%W_s$ procedure rated the HCP as "unacceptable" for all test comparisons (Table 15). In contrast, the $STDV_s$ procedure gave a mixture of all three ratings for different combinations of audiometric frequencies and test comparisons (Table 16). This procedure rated the HCP as "marginal" in 10 of 18 test comparisons (56%) and as "acceptable" in 7 of 18 (39%) test comparisons. The mean score for this procedure was 1.3 (i.e., between "marginal" and "acceptable" ratings, but more toward the "marginal" range). The $STDVA_s$ procedure rated the HCP as "acceptable" in 3 of 9 tests (33%) and "marginal" in 6 of 9 (67%) tests (Table 17). The mean score for this procedure was 1.3 (i.e., between "marginal" and "acceptable" ratings, but more toward the "marginal" range). When results of the $\%W_s$ and either of $STDV_s$ or $STDVA_s$ procedures were summarized for men in Cohort-B4, the HCP received a mean score in the range of 0.7-0.9 which is clearly toward

the marginal range.

Women (N=61): For women, the $\%W_s$ procedure rated the HCP between "unacceptable" and "marginal" for all test comparisons (Table 18). The mean of the $\%W_s$ values was calculated to be 30.1 (unacceptable range: >30), assigning "unacceptable" rating to the HCP. However, the mean score for the procedure was 0.7 indicating a rating between "unacceptable" and "marginal". Table 19 shows the ratings for different combinations of audiometric frequencies and test comparisons using the $STDV_s$ procedure. The procedure rated the HCP as "acceptable" in 12 of 18 (67%) test comparisons and received a mean score of 1.6, which is toward the "acceptable" range. A similar rating was assigned by the $STDVA_s$ procedure (Table 20). However, when results of the $\%W_s$ and either of $STDV_s$ or $STDVA_s$ procedures were summarized for women in Cohort-B4, the HCP was rated toward the marginal range with the mean scores of 1.2 and 1.1. Thus, since the overall rating was "marginal" for the earlier cohorts (Cohort-A4 and Cohort-A8) and the later cohort (Cohort-B4), we conclude that no change in program performance was found over time.

DISCUSSION

In this report we describe the application of the DANS method for evaluating the effectiveness of hearing conservation programs (HCPs) to a large set of audiometric data collected from civilian workers in the U.S. Army during 1976-1992. All three cohorts were predominantly white males under the age of 45.

Each of the ADBA procedures rated the HCP as "marginal" for both men and women. Therefore, the overall performance of the Army's HCP was assessed to be "marginal" using these procedures. However, the sample used for program assessment raises at least two questions: Is the sample size adequate? Is the selected sample size representative of the target population? First, the assessment was based on less than 1.5% of the study population that qualified to enter into the study in accordance with the DANS criteria. On the basis of this proportion, one will need a study population of 2,000 workers in an HCP to obtain the minimum number of workers (N=30) necessary to use the ADBA procedures for evaluating HCPs.[17] This requirement limits evaluation of the HCPs at many small and medium sized businesses whose work force is below 2,000. Second, the issue of representativeness is very important. The question is whether the risk of developing hearing loss in those who stayed long enough in the program to qualify for the restrictive DANS criteria was similar to those who did not qualify. In a study conducted by Adera et al,[18] to assess the DANS method, they reported that those workers who did not meet the DANS criteria had a Risk Ratio of 9.1 as opposed to 2.3 for those who qualified to enter, and concluded that the

DANS method may systematically exclude workers at high risk of hearing loss from analyses.

Another observation of concern in the application of the DANS method, was the extreme rating variability within and between procedures ascribing the method as unstable. For example, the $STDV_s$ procedure shown in Table 13 reveals that 22%, 20%, and 58% of the test comparisons were rated as "unacceptable", "marginal", and "acceptable" respectively. In addition, we observed that the $\%W_s$, and the $\%BW_s$ procedures generally assigned a lower rating to the program than either of the standard deviation procedures. Further application of the DANS method to different data sets is needed to confirm or refute the findings of this study.

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Table 1. Distribution of Number of Tests, Duration of Follow-up and Gender in Three Selected Cohorts of Civilian Workers in the U.S. Army.

Characteristics	Cohort-A4	Cohort-A8	Cohort-B4
Number of Tests	4	8	4
Duration of Follow-up	1982-1985	1982-1989	1988-1991
Males	1094	246	985
Females	99	14	61
Males and Females	1193	260	1046

Table 2. Distribution of Sociodemographic Factors by Gender at Baseline for Cohort-A4* Workers During 1982-1985 (N=1193)

Sociodemographic Factors		Males		Females		Total	
		N	%	N	%	N	%
Age Group							
24 or younger		39	3.6	3	3.1	42	3.5
25-34		459	42.0	42	42.4	501	42.0
35-44		384	35.1	34	34.3	418	35.1
45-54		200	18.3	18	18.2	218	18.3
55-64		11	1.0	2	2.0	13	1.1
	Total	1093#	100	99	100	1192	100
Race							
Non-Hispanic Black		120	11.0	15	15.2	135	11.3
Hispanic		69	6.3	5	5.1	74	6.2
American Indian or Alaskan Native		21	1.9	4	4.0	25	2.1
Asian or Pacific Islander & Hawaiian		38	3.5	7	7.1	45	3.8
White, Non-Hispanic		843	77.3	68	68.7	911	76.6
	Total	1091†	100	99	100	1190	100
Highest Education Attained							
Elementary School		21	1.9	3	3.0	24	2.0
High School		616	56.5	52	52.5	668	56.1
Terminal Occupation Program		123	11.3	14	14.1	137	11.5
College		313	28.7	29	29.3	342	28.7
Post College		18	1.7	1	1.0	19	1.6
	Total	1091‡	100	99	100	1190	100

* Those who met the ANSI S12.13-1991 criteria for at least four consecutive tests.
# Information on age was not obtained for 1 subject.
†,‡ Information on race and education was not obtained for 3 subjects.

Table 3. Distribution of Sociodemographic Factors by Gender at Baseline for Cohort-A8* Workers During 1982-1989 (N=260)

Sociodemographic Factors	Males		Females		Total	
	N	%	N	%	N	%
Age Group						
24 or younger	5	2.0	0	0.0	5	1.9
25-34	106	43.1	6	42.9	112	43.1
35-44	85	34.6	5	35.7	90	34.6
45-54	48	19.5	3	21.4	51	19.6
55-64	2	0.8	0	0.0	2	0.8
Total	246	100	14	100	260	100
Race						
Non-Hispanic Black	16	6.5	1	7.1	17	6.5
Hispanic	4	1.6	0	0.0	4	1.5
American Indian or Alaskan Native	5	2.0	0	0.0	5	1.9
Asian or Pacific Islander & Hawaiian	16	6.5	1	7.1	17	6.5
White, Non-Hispanic	205	83.3	12	85.7	217	83.5
Total	246	100	14	100	260	100
Highest Education Attained						
Elementary School	5	2.0	0	0.0	5	1.9
High School	136	55.3	5	35.7	141	54.2
Terminal Occupation Program	36	14.6	2	14.3	38	14.6
College	64	26.0	7	50.0	71	27.3
Post College	5	2.0	0	0.0	5	1.9
Total	246	100	14	100	260	100

*Those who met the ANSI S12.13-1991 criteria for at least eight consecutive tests.

Table 4. Distribution of Sociodemographic Factors by Gender at Baseline for Cohort-B4* Workers During 1988-1991 (N=1046)

Sociodemographic Factors	Males		Females		Total	
	N	%	N	%	N	%
Age Group						
24 or younger	38	4.1	2	3.4	40	4.1
25-34	222	24.0	21	35.6	243	24.7
35-44	414	44.7	23	39.0	437	44.3
45-54	193	20.8	11	18.6	204	20.7
55-64	56	6.0	2	3.4	58	5.9
65 or older	4	0.4	0	0.0	4	0.4
Total	927#	100	59†	100	986	100
Race						
Non-Hispanic Black	76	7.8	6	9.8	82	7.9
Hispanic	20	2.1	0	0.0	20	1.9
American Indian or Alaskan Native	15	1.5	3	4.9	18	1.7
Asian or Pacific Islander & Hawaiian	19	1.9	3	4.9	22	2.1
White, Non-Hispanic	847	86.7	49	80.3	896	86.3
Total	977‡	100	61	100	1038	100
Highest Education Attained						
Elementary School	12	1.2	0	0.0	12	1.2
High School	560	57.3	25	31.9	585	56.4
Terminal Occupation Program	95	9.7	5	10.6	100	9.6
College	280	28.7	30	55.3	310	29.9
Post College	30	3.1	1	2.1	31	3.0
Total	977‡	100	61	100	1038	100

* Those who met the ANSI S12.13-1991 criteria for at least four consecutive tests.
# Information on age was not obtained for 58 subjects.
† Information on age was not obtained for 2 subjects.
‡ Information on race and education was not obtained for 8 subjects.

Table 5. Percent Worse Sequential Results with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Test Comparison for Male Civilian Workers in the U.S. Army During 1982-1985 (Cohort-A4, N=1094).

Test Comparison	Total Number	Percent Worse Sequential	HCP Rating†	Range‡
1-2	1094	69.4	Unacceptable	>30
2-3	1094	24.9	Marginal	20-30
3-4	1094	34.5	Unacceptable	>30
Mean Percent Worse Sequential for All Test Comparisons=42.9 (Unacceptable)				

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 6. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Frequency for Male Civilian Workers in the U.S. Army During 1982-1985 (Cohort-A4, N=1094).

	Test 1-2			Test 2-3			Test 3-4		
Frequency (Hz)	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡
500	12.4	Unaccept.	>7	7.3	Unaccept.	>7	5.6	Accept.	<6
1000	11.2	Unaccept.	>7	5.3	Accept.	<6	4.2	Accept.	<6
2000	15.2	Unaccept.	>7	4.6	Accept.	<6	4.4	Accept.	<6
3000	23.7	Unaccept.	>10	6.1	Accept.	<7	5.5	Accept.	<7
4000	26.4	Unaccept.	>10	6.8	Accept.	<7	6.3	Accept.	<7
6000	27.5	Unaccept.	>12	9.2	Marginal	9-12	8.9	Marginal	9-12

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 7. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Averaged Frequencies for Male Civilian Workers in the U.S. Army During 1982-1985 (Cohort-A4, N=1094).

	Test 1-2			Test 2-3			Test 3-4		
Frequency Averaged (KHz)	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡
.5,1,2,3	12.8	Unaccept.	>6.5	4.4	Accept.	<4.5	3.6	Accept.	<4.5
2,3,4	19.7	Unaccept.	>7.5	4.8	Accept.	<5.5	4.4	Accept.	<5.5
3,4,6	23.8	Unaccept.	>8.5	5.7	Accept.	<6	5.2	Accept.	<6

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 8. Percent Worse Sequential Results with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Test Comparison for Female Civilian Workers in the U.S. Army During 1982-1985 (Cohort-A4, N=99).

Test Comparison	Total Number	Percent Worse Sequential	HCP Rating†	Range‡
1-2	99	51.5	Unacceptable	>30
2-3	99	26.3	Marginal	20-30
3-4	99	31.3	Unacceptable	>30
Mean Percent Worse Sequential for All Test Comparisons=36.4 (Unacceptable)				

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 9. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Frequency for Female Civilian Workers in the U.S. Army During 1982-1985 (Cohort-A4, N=99).

	Test 1-2			Test 2-3			Test 3-4		
Frequency (Hz)	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡
500	11.7	Unaccept.	>7	11.0	Unaccept.	>7	9.0	Unaccept.	>7
1000	9.4	Unaccept.	>7	6.1	Marginal	6-7	5.3	Accept.	<6
2000	10.3	Unaccept.	>7	5.4	Accept.	<6	5.6	Accept.	<6
3000	17.8	Unaccept.	>10	4.5	Accept.	<7	4.6	Accept.	<7
4000	21.5	Unaccept.	>10	4.9	Accept.	<7	4.7	Accept.	<7
6000	22.1	Unaccept.	>12	7.6	Accept.	<9	8.3	Accept.	<9

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 10. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Averaged Frequencies for Female Civilian Workers in the U.S. Army During 1982-1985 (Cohort-A4, N=99).

	Test 1-2			Test 2-3			Test 3-4		
Frequency Averaged (KHz)	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡
.5,1,2,3	8.7	Unaccept.	>6.5	5.6	Marginal	4.5-6.5	5.1	Marginal	4.5-6.5
2,3,4	14.4	Unaccept.	>7.5	4.1	Accept.	<5.5	4.2	Accept.	<5.5
3,4,6	18.5	Unaccept.	>8.5	4.1	Accept.	<6	4.4	Accept.	<6

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 11. Percent Worse Sequential Results with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Test Comparison for Male Civilian Workers in the U.S. Army During 1982-1989 (Cohort-A8, N=246).

Test Comparison	Total Number	Percent Worse Sequential	HCP Rating†	Range‡
1-2	246	69.5	Unacceptable	>30
2-3	246	26.0	Marginal	20-30
3-4	246	30.1	Marginal	20-30
5-6	246	22.4	Marginal	17-27
6-7	246	37.4	Unacceptable	>27
7-8	246	33.3	Unacceptable	>27
Mean Percent Worse Sequential for All Test Comparisons=36.5 (Unacceptable)				

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 12. Percent Better or Worse Sequential Results with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Test Comparison for Male Civilian Workers in the U.S. Army During 1982-1989 (Cohort-A8, N=246).

Test Comparison	Total Number	%BW Sequential	HCP Rating†	Range‡
5-6	246	43.9	Unacceptable	>40
6-7	246	55.7	Unacceptable	>40
7-8	246	53.7	Unacceptable	>40
Mean Percent Better or Worse Sequential for All Test Comparisons=51.1 (Unacceptable)				

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 13. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Frequency for Male Civilian Workers in the U.S. Army During 1982-1989 (Cohort-A8, N=246).

	Test 1-2			Test 2-3			Test 3-4			Test 5-6			Test 6-7			Test 7-8		
Freq (Hz)	Std Dev	HCP Rating†	Range‡	Std Dev	HCP Rating†	Range‡	Std Dev	HCP Rating†	Range‡	Std Dev	HCP Rating†	Range‡	Std Dev	HCP Rating†	Range‡	Std Dev	HCP Rating†	Range‡
500	11.6	U*	>7	6.0	A	<6	5.5	A	<6	8.1	U	>7	8.4	U	>7	5.9	M	5-7
1000	10.6	U	>7	4.7	A	<6	4.0	A	<6	4.8	A	<5	5.2	M	5-7	5.4	M	5-7
2000	15.1	U	>7	4.3	A	<6	3.7	A	<6	4.6	A	<5	4.7	A	<5	5.7	M	5-7
3000	22.3	U	>10	4.8	A	<7	4.8	A	<7	5.2	A	<6	5.1	A	<6	6.6	M	6-8
4000	25.3	U	>10	5.8	A	<7	5.3	A	<7	6.1	A	<7	5.8	A	<7	6.4	A	<7
6000	26.7	U	>12	8.2	A	<9	7.4	A	<9	6.7	A	<8	8.2	M	8-11.5	8.7	M	8-11.5

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.
* U=Unacceptable, M=Marginal, A=Acceptable.

Table 14. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Ratings and Criterion Range by Averaged Frequencies for Male Civilian Workers in the U.S. Army During 1982-1989 (Cohort-A8, N=246).

	Test 1-2			Test 2-3			Test 3-4			Test 5-6			Test 6-7			Test 7-8		
Freq Avrgd (KHz)	Std Dev	HCP Rating†	Range‡	Std Dev	HCP Rating†	Range ‡	Std Dev	HCP Rating†	Range ‡	Std Dev	HCP Rating†	Range‡	Std Dev	HCP Rating †	Range ‡	Std Dev	HCP Rating †	Range ‡
.5,1,2,3	12.2	U*	>6.5	3.8	A	<4.5	3.4	A	<4.5	4.7	M	4-5.5	4.5	M	4-5.5	4.6	M	4-5.5
2,3,4	18.8	U	>7.5	4.1	A	<5.5	3.7	A	<5.5	4.4	A	<5	4.1	A	<5	4.9	A	<5
3,4,6	22.3	U	>8.5	4.7	A	<6	4.1	A	<6	4.5	A	<6	4.4	A	<6	5.1	A	<6

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.
* U=Unacceptable, A=Acceptable, M=Marginal.

Table 15. Percent Worse Sequential Results with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Test Comparison for Male Civilian Workers in the U.S. Army During 1988-1991 (Cohort-B4, N=985).

Test Comparison	Total Number	Percent Worse Sequential	HCP Rating†	Range‡
1-2	985	36.9	Unacceptable	>30
2-3	985	34.1	Unacceptable	>30
3-4	985	35.9	Unacceptable	>30
Mean Percent Worse Sequential for All Test Comparisons=35.6 (Unacceptable)				

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 16. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Frequency for Male Civilian Workers in the U.S. Army During 1988-1991 (Cohort-B4, N=985).

	Test 1-2			Test 2-3			Test 3-4		
Frequency (Hz)	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡
500	7.4	Unaccept.	>7	6.0	Marginal	6-7	5.9	Accept.	<6
1000	5.2	Accept.	<6	4.7	Accept.	<6	4.4	Accept.	<6
2000	6.3	Marginal	6-7	5.2	Accept.	<6	5.9	Accept.	<6
3000	7.8	Marginal	7-10	6.6	Accept.	<7	7.0	Marginal	7-10
4000	9.0	Marginal	7-10	8.2	Marginal	7-10	8.1	Marginal	7-10
6000	11.8	Marginal	9-12	10.7	Marginal	9-12	10.6	Marginal	9-12

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 17. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Averaged Frequencies for Male Civilian Workers in the U.S. Army During 1988-1991 (Cohort-B4, N=985).

Frequency	Test 1-2			Test 2-3			Test 3-4		
Averaged (KHz)	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡
.5,1,2,3	5.3	Marginal	4.5-6.5	4.2	Accept.	<4.5	4.3	Accept.	<4.5
2,3,4	6.6	Marginal	5.5-7.5	5.3	Accept.	<5.5	5.5	Marginal	5.5-7.5
3,4,6	7.5	Marginal	6-8.5	6.0	Marginal	6-8.5	6.2	Marginal	6-8.5

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 18. Percent Worse Sequential Results with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Test Comparison for Female Civilian Workers in the U.S. Army During 1988-1991 (Cohort-B4, N=61).

Test Comparison	Total Number	Percent Worse Sequential	HCP Rating†	Range‡
1-2	61	27.9	Marginal	20-30
2-3	61	26.2	Marginal	20-30
3-4	61	36.1	Unacceptable	>30
Mean Percent Worse Sequential for All Test Comparisons=30.1 (Unacceptable)				

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 19. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Frequency for Female Civilian Workers in the U.S. Army During 1988-1991 (Cohort-B4, N=61).

	Test 1-2			Test 2-3			Test 3-4		
Frequency (Hz)	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡
500	7.0	Unaccept.	>7	5.9	Accept.	<6	5.2	Accept.	<6
1000	6.3	Marginal	6-7	3.7	Accept.	<6	3.4	Accept.	<6
2000	6.2	Marginal	6-7	4.0	Accept.	<6	3.8	Accept.	<6
3000	9.6	Marginal	7-10	5.0	Accept.	<7	4.8	Accept.	<7
4000	9.8	Marginal	7-10	5.1	Accept.	<7	5.1	Accept.	<7
6000	12.9	Unaccept.	>12	7.0	Accept.	<9	8.7	Accept.	<9

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 20. Standard Deviation of the Average Binaural Differences with Associated Hearing Conservation Program (HCP) Rating and Criterion Range by Averaged Frequencies for Female Civilian Workers in the U.S. Army During 1988-1991 (Cohort-B4, N=61).

	Test 1-2			Test 2-3			Test 3-4		
Frequency Averaged (KHz)	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡	Std. Dev.	HCP Rating†	Range‡
.5,1,2,3	6.1	Marginal	4.5-6.5	3.5	Accept.	<4.5	3.1	Accept.	<4.5
2,3,4	7.7	Unaccept.	>7.5	3.8	Accept.	<5.5	3.7	Accept.	<5.5
3,4,6	9.7	Unaccept.	>8.5	3.9	Accept.	<6	4.4	Accept.	<6

† Draft American National Standard (ANSI S12.13 - 1991) Rating Scale.
‡ Draft American National Standard (ANSI S12.13 - 1991) Recommended Criterion Range.

Table 21. Summary of Different Audiometric Database Analysis Procedures Using Mean Rating Scores* by Gender Among Civilian Workers in the U.S Army.

Procedure	M+F Mean Score (Rating)	Male Mean Score (Rating)	Female Mean Score (Rating)
Cohort-A4	*(N=1193)*	*(N=1094)*	*(N=99)*
%Ws	0.3 (U)	0.3 (U)	0.3 (U)
STDVs†	1.1 (M)	1.1 (M)	1.1 (M)
STDVAs‡	1.2 (M)	1.2 (M)	1.1 (M)
Overall Mean Score (Rating)	0.9 (M)	0.9 (M)	0.8 (M)
Mean of %Ws and STDVs	0.7 (M)	0.7 (M)	0.7 (M)
Mean of %Ws and STDVAs	0.8 (M)	0.8 (M)	0.7 (M)
Cohort-A8	*(N=260)*	*(N=246)*	*(N=14)*
%Ws	0.5 (M)	0.5 (M)	N/A
STDVs	1.4 (M)	1.3 (M)	N/A
STDVAs	1.5 (A)	1.4 (M)	N/A
%BW	0.0 (U)	0.0 (U)	N/A
Overall Mean Score	0.9 (M)	0.8 (M)	N/A
Mean of %Ws, STDVs and %BWs	0.6 (M)	0.6 (M)	N/A
Mean of %Ws, STDVAs and %BWs	0.7 (M)	0.6 (M)	N/A
Cohort-B4	*(N=1046)*	*(N=985)*	*(N=61)*
%Ws	0.0 (U)	0.0 (U)	0.7 (M)
STDVs	1.3 (M)	1.3 (M)	1.6 (A)
STDVAs	1.4 (M)	1.3 (M)	1.4 (M)
Overall Mean Score	0.9 (M)	0.9 (M)	1.2 (M)
Mean of %Ws and STDVs	0.7 (M)	0.7 (M)	1.2 (M)
Mean of %Ws and STDVAs	0.7 (M)	0.7 (M)	1.1 (M)

* Each of the HCP ratings for different test comparisons and frequencies were assigned scores as follows: Unacceptable (U)=0, Marginal (M)=1, Acceptable (A)=2. Then, the mean score for each procedure by gender was rated as follows: (U=0.0-0.4; M=0.5-1.4; A=1.5-2.0).
† Standard Deviations of Binaural HTLs.
‡ Standard Deviations of Averaged Frequency Binaural HTLs.

Table 22. Comparison of Methods for Summarizing HCP Ratings from ADBA Procedures for Male Civilian Workers in the U.S. Army.

Procedure	Mean Score Rating[1]	Mean Standard Score Rating[2]	Median Standard Score Rating[3]
Cohort-A4	*(N=1094)*		
%Ws	0.3 U	2.3 U	1.5 U
STDVs[4]	1.1 M	1.9 U	-0.1 A
STDVAs[5]	1.2 M	1.8 U	-0.1 A
Overall Mean Score (Rating)	0.9 M	2.0 U	0.4 M
Mean of %Ws and STDVs	0.7 M	2.1 U	0.7 M
Mean of %Ws and STDVAs	0.8 M	2.1 U	0.7 M
Cohort-A8	*(N=246)*		
%Ws	0.5 M	1.8 U	1.3 U
STDVs	1.3 M	0.8 M	-0.2 A
STDVAs	1.4 M	0.7 M	-0.4 A
%BWs	0.0 U	1.8 U	2.0 U
Overall Mean Score	0.8 M	1.3 U	0.7 M
Mean of %Ws, STDVs and %BWs	0.6 M	1.5 U	1.0 M
Mean of %Ws, STDVAs and %BWs	0.6 M	1.4 U	1.0 M
Cohort-B4	*(N=985)*		
%Ws	0.0 U	1.6 U	1.6 U
STDVs	1.3 M	0.0 M	0.2 M
STDVAs	1.3 M	0.1 M	0.0 M
Overall Mean Score	0.9 M	0.6 M	0.6 M
Mean of %Ws and STDVs	0.7 M	0.8 M	0.9 M
Mean of %Ws and STDVAs	0.7 M	0.9 M	0.8 M

1. Each of the HCP ratings for different test comparisons and frequencies was assigned the following scores: 0=U (Unacceptable), 1=M (Marginal), or 2=A (Acceptable). The mean of the scores for each procedure was rounded off to the nearest integer and rated again: U if mean=0, M if mean=1, A if mean=2.

2, 3. The Standard Score is defined as follows: below 0 is Acceptable (A), 0 to 1 is Marginal (M), above 1 is Unacceptable (U).

4. Standard Deviations of Binaural HTLs.

5. Standard Deviations of Averaged Frequency Binaural HTLs.

Table 23. Comparison of Methods for Summarizing HCP Ratings from ADBA Procedures for Female Civilian Workers in the U.S. Army.

Procedure	Mean Score Rating[1]	Mean Standard Score Rating[2]	Median Standard Score Rating[3]
Cohort-A4	*(N=99)*		
%Ws	0.3 U	1.6 U	1.1 U
STDVs[4]	1.1 M	1.6 U	-0.1 A
STDVAs[5]	1.1 M	1.1 U	0.3 M
Overall Mean Score (Rating)	0.8 M	1.4 U	0.4 M
Mean of %Ws and STDVs	0.7 M	1.6 U	0.5 M
Mean of %Ws and STDVAs	0.7 M	1.4 U	0.7 M
Cohort-B4	*(N=61)*		
%Ws	0.7 M	1.0 M	0.8 M
STDVs	1.6 A	-0.5 A	-0.6 A
STDVAs	1.4 M	-0.1 A	-0.6 A
Overall Mean Score	1.2 M	0.1 M	-0.1 A
Mean of %Ws and STDVs	1.2 M	0.3 M	0.1 M
Mean of %Ws and STDVAs	1.1 M	0.5 M	0.1 M

1. Each of the HCP ratings for different test comparisons and frequencies was assigned the folowing scores: 0=U (Unacceptable), 1=M (Marginal), or 2=A (Acceptable). The mean of the scores for each procedure was rounded off to the nearest integer and rated again: U if mean=0, M if mean=1, A if mean=2.

2, 3. The Standard Score is defined as follows: below 0 is Acceptable (A), 0 to 1 is Marginal (M), above 1 is Unacceptable (U).

4. Standard Deviations of Binaural HTLs.

5. Standard Deviations of Averaged Frequency Binaural HTLs.

Table 24. Standard Scores* from %Ws, STDVs and STDVAs Procedures According to Test Comparisons of Audiometric Tests of Civilian Workers During 1982-1985 in the U.S. Army. (Cohort-A4, N=1193)

Procedure	Marginal Range	Test 1-2 Row Score	Test 1-2 Std Score	Test 2-3 Row Score	Test 2-3 Std Score	Test 3-4 Row Score	Test 3-4 Std Score
Individual Freq. (STDVs)							
0.5 KHz	6 to 7	12.4	6.4	7.6	1.6	6.0	0.0
1 KHz	6 to 7	11.1	5.1	5.4	-0.6	4.3	-1.7
2 KHz	6 to 7	14.9	8.9	4.7	-1.3	4.5	-1.5
3 KHz	7 to 10	23.4	5.5	6.0	-0.3	5.4	-0.5
4 KHz	7 to 10	26.3	6.4	6.6	-0.1	6.2	-0.3
6 KHz	9 to 12	27.2	6.1	9.1	0.0	8.8	-0.1
Mean of Standard Scores=1.9 (Unacceptable)**							
Averaged Freq. (STDVAs)							
0.5,1,2,3 KHz	4.5 to 6.5	12.5	4.0	4.5	0.0	3.8	-0.4
2,3,4 KHz	5.5 to 7.5	19.4	7.0	4.8	-0.4	4.4	-0.6
3,4,6 KHz	6 to 8.5	23.6	7.0	5.6	-0.2	5.1	-0.4
Mean of Standard Scores=1.8 (Unacceptable)							
%Ws							
Percentage	20 to 30	67.9	4.8	25.0	0.5	34.2	1.4
Mean of Standard Scores=2.2 (Unacceptable)							

* Standard Score is a linear transformation of row score. The formula is:

$$stdscr=(rowscr-l)/(h-l)$$

stdscr is standard score, *rowscr* is row score, *l* is the lower limit of the row marginal range, and *h* is the upper limit of the row marginal range.

** Standard Score Marginal Range is 0 to 1. *Stdscr* below 0 is acceptable (A), between 0 and 1 is Marginal (M), above 1 is Unacceptable (U)

Table 25. Standard Scores* from %Ws, STDVs and STDVAs Procedures According to Test Comparisons of Audiometric Tests of Male Civilian Workers During 1982-1985 in the U.S. Army. (Cohort-A4, N=1094)

Procedure	Marginal Range	Test 1-2 Row Score	Test 1-2 Std Score	Test 2-3 Row Score	Test 2-3 Std Score	Test 3-4 Row Score	Test 3-4 Std Score
Individual Freq. (STDVs)							
0.5 KHz	6 to 7	12.4	6.4	7.3	1.3	5.6	-0.4
1 KHz	6 to 7	11.2	5.2	5.3	-0.7	4.2	-1.8
2 KHz	6 to 7	15.2	9.2	4.6	-1.4	4.4	-1.6
3 KHz	7 to 10	23.7	5.6	6.1	-0.3	5.5	-0.5
4 KHz	7 to 10	26.4	6.5	6.8	-0.1	6.3	-0.2
6 KHz	9 to 12	27.5	6.2	9.2	0.1	8.9	0.0
Mean of Standard Scores=1.9 (Unacceptable)**							
Averaged Freq. (STDVAs)							
0.5,1,2,3 KHz	4.5 to 6.5	12.8	4.1	4.4	0.0	3.6	-0.4
2,3,4 KHz	5.5 to 7.5	19.7	7.1	4.8	-0.3	4.4	-0.5
3,4,6 KHz	6 to 8.5	23.8	7.1	5.7	-0.1	5.2	-0.3
Mean of Standard Scores=1.8 (Unacceptable)							
%Ws							
Percentage	20 to 30	69.4	4.9	24.9	0.5	34.5	1.5
Mean of Standard Scores=2.3 (Unacceptable)							

* Standard Score is a linear transformation of row score. The formula is:

$$stdscr=(rowscr-l)/(h-l)$$

stdscr is standard score, *rowscr* is row score, *l* is the lower limit of the row marginal range, and *h* is the upper limit of the row marginal range.

** Standard Score Marginal Range is 0 to 1. *Stdscr* below 0 is acceptable (A), between 0 and 1 is Marginal (M), above 1 is Unacceptable (U).

Table 26. Standard Scores* from %Ws, STDVs and STDVAs Procedures According to Test Comparisons of Audiometric Tests of Female Civilian Workers During 1982-1985 in the U.S. Army. (Cohort-A4, N=99)

Procedure	Marginal Range	Test 1-2 Row Score	Test 1-2 Std Score	Test 2-3 Row Score	Test 2-3 Std Score	Test 3-4 Row Score	Test 3-4 Std Score
Individual Freq. (STDVs)							
0.5 KHz	6 to 7	11.7	5.7	11.0	5.0	9.0	3.0
1 KHz	6 to 7	9.4	3.4	6.1	0.0	5.3	-0.7
2 KHz	6 to 7	10.3	4.3	5.4	-0.6	5.6	-0.4
3 KHz	7 to 10	17.8	3.6	4.5	-0.8	4.6	-0.8
4 KHz	7 to 10	21.5	4.8	4.9	-0.7	4.7	-0.8
6 KHz	9 to 12	22.1	4.4	7.6	-0.5	8.3	-0.2
Mean of Standard Scores=1.6 (Unacceptable)**							
Averaged Freq. (STDVAs)							
0.5,1,2,3 KHz	4.5 to 6.5	8.7	2.1	5.6	0.6	5.1	0.3
2,3,4 KHz	5.5 to 7.5	14.4	4.5	4.1	-0.7	4.2	-0.7
3,4,6 KHz	6 to 8.5	18.5	5.0	4.1	-0.8	4.4	-0.6
Mean of Standard Scores=1.1 (Unacceptable)							
%Ws							
Percentage	20 to 30	51.5	3.2	26.3	0.6	31.3	1.1
Mean of Standard Scores=1.6 (Unacceptable)							

* Standard Score is a linear transformation of row score. The formula is:

$$stdscr=(rowscr-l)/(h-l)$$

stdscr is standard score, *rowscr* is row score, l is the lower limit of the row marginal range, and h is the upper limit of the row marginal range.

** Standard Score Marginal Range is 0 to 1. *Stdscr* below 0 is acceptable (A), between 0 and 1 is Marginal (M), above 1 is Unacceptable (U).

Table 27. Standard Scores* from %Ws, %BWs, STDVs and STDVAs Procedures According to Test Comparisons of Audiometric Tests of Civilian Workers During 1982-1989 in the U.S. Army. (Cohort-A8, N=260)

Procedure	Marginal Range	Test 1-2 Row Scr	Test 1-2 Std Scr	Test 2-3 Row Scr	Test 2-3 Std Scr	Test 3-4 Row Scr	Test 3-4 Std Scr	Marginal Range	Test 5-6 Row Scr	Test 5-6 Std Scr	Test 6-7 Row Scr	Test 6-7 Std Scr	Test 7-8 Row Scr	Test 7-8 Std Scr
Individual Freq. (STDVa)														
0.5 KHz	6 to 7	11.5	5.5	5.9	-0.1	5.4	-0.6	5 to 7	7.9	1.5	8.2	1.6	5.8	0.4
1 KHz	6 to 7	10.4	4.4	4.6	-1.4	4.0	-2.0	5 to 7	4.7	-0.1	5.1	0.0	5.3	0.2
2 KHz	6 to 7	14.8	8.8	4.3	-1.8	3.7	-2.3	5 to 7	4.5	-0.3	4.6	-0.2	5.6	0.3
3 KHz	7 to 10	22.1	5.0	4.8	-0.7	4.7	-0.8	6 to 8	5.1	-0.4	5.0	-0.5	6.5	0.3
4 KHz	7 to 10	25.1	6.0	5.8	-0.4	5.3	-0.6	7 to 10	6.1	-0.3	5.8	-0.4	6.4	-0.2
6 KHz	9 to 12	26.5	5.8	8.2	-0.3	7.4	-0.5	8 to 11.5	6.7	-0.4	8.0	0.0	8.6	0.2
									Mean of Standard Scores=0.7 (Marginal)**					
Averaged Freq. (STDVAs)														
0.5,1,2,3 KHz	4.5 to 6.5	12.0	3.7	3.7	-0.4	3.3	-0.6	4 to 5.5	4.6	0.4	4.4	0.3	4.6	0.4
2,3,4 KHz	5.5 to 7.5	18.5	6.5	4.0	-0.7	3.6	-0.9	5 to 7	4.3	-0.3	4.1	-0.5	4.9	-0.1
3,4,6 KHz	6 to 8.5	22.2	6.5	4.6	-0.6	4.0	-0.8	6 to 8.5	4.4	-0.6	4.3	-0.7	5.1	-0.4
									Mean of Standard Scores=0.6 (Marginal)					
%Ws														
Percentage	20 to 30	68.8	4.9	25.8	0.6	29.2	0.9	17 to 27	23.1	0.6	36.5	2.0	33.1	1.6
									Mean of Standard Scores=1.8 (Unacceptalbe)					
%BWs														
Percentage								26 to 40	44.6	1.3	55.0	2.1	53.8	2.0
									Mean of Standard Scores=1.8 (Unacceptable)					

* Standard Score is a linear transformation of row score. The formula is:

$$stdscr=(rowscr-l)/(h-l)$$

stdscr is standard score, *rowscr* is row score, *l* is the lower limit of the row marginal range, and *h* is the upper limit of the row marginal range.

** Standard Score Marginal Range is 0 to 1. *Stdscr* below 0 is acceptable (A), between 0 and 1 is Marginal (M), above 1 is Unacceptable (U).

Table 28. Standard Scores* from %Ws, %BWs, STDVs and STDVAs Procedures According to Test Comparisons of Audiometric Tests of Male Civilian Workers During 1982-1989 in the U.S. Army. (Cohort-A8, N=246)

Procedure	Marginal Range	Test 1-2 Row Scr	Test 1-2 Std Scr	Test 2-3 Row Scr	Test 2-3 Std Scr	Test 3-4 Row Scr	Test 3-4 Std Scr	Marginal Range	Test 5-6 Row Scr	Test 5-6 Std Scr	Test 6-7 Row Scr	Test 6-7 Std Scr	Test 7-8 Row Scr	Test 7-8 Std Scr
Individual Freq. (STDVs)														
0.5 KHz	6 to 7	11.6	5.6	6.0	0.0	5.5	-0.5	5 to 7	8.1	1.5	8.4	1.7	5.9	0.4
1 KHz	6 to 7	10.6	4.6	4.7	-1.3	4.0	-2.0	5 to 7	4.8	-0.1	5.2	0.1	5.4	0.2
2 KHz	6 to 7	15.1	9.1	4.3	-1.7	3.7	-2.3	5 to 7	4.6	-0.2	4.7	-0.2	5.7	0.3
3 KHz	7 to 10	22.3	5.1	4.8	-0.7	4.8	-0.7	6 to 8	5.2	-0.4	5.1	-0.5	6.6	0.3
4 KHz	7 to 10	25.3	6.1	5.8	-0.4	5.8	-0.4	7 to 10	6.1	-0.3	5.8	-0.4	6.4	-0.2
6 KHz	9 to 12	26.7	5.9	8.2	-0.3	7.4	-0.5	8 to 11.5	6.7	-0.4	8.2	0.0	8.7	0.2
									Mean of Standard Scores=0.8 (Marginal)**					
Averaged Freq. (STDVAs)														
0.5,1,2,3 KHz	4.5 to 6.5	12.2	3.9	3.8	-0.4	3.4	-0.6	4 to 5.5	4.7	0.4	4.5	0.4	4.6	0.4
2,3,4 KHz	5.5 to 7.5	18.8	6.6	4.1	-0.7	3.7	-0.9	5 to 7	4.4	-0.3	4.1	-0.5	4.9	0.0
3,4,6 KHz	6 to 8.5	22.3	6.5	4.7	-0.5	4.1	-0.8	6 to 8.5	4.5	-0.6	4.4	-0.7	5.1	-0.4
									Mean of Standard Scores=0.7 (Marginal)					
%Ws														
Percentage	20 to 30	69.5	5.0	26.0	0.6	30.1	1.0	17 to 27	22.4	0.5	37.4	2.0	33.3	1.6
									Mean of Standard Scores=1.8 (Unacceptalbe)					
%BWs														
Percentage								26 to 40	43.9	1.3	55.7	2.1	53.7	2.0
									Mean of Standard Scores=1.8 (Unacceptable)					

* Standard Score is a linear transformation of row score. The formula is:

$$stdscr=(rowscr-l)/(h-l)$$

stdscr is standard score, *rowscr* is row score, *l* is the lower limit of the row marginal range, and *h* is the upper limit of the row marginal range.

** Standard Score Marginal Range is 0 to 1. *Stdscr* below 0 is acceptable (A), between 0 and 1 is Marginal (M), above 1 is Unacceptable (U).

Table 29. Standard Scores* from %Ws, STDVs and STDVAs Procedures According to Test Comparisons of Audiometric Tests of Civilian Workers During 1988-1991 in the U.S. Army. (Cohort-B4, N=1046)

		Test 1-2		Test 2-3		Test 3-4	
	Marginal Range	Row Score	Std Score	Row Score	Std Score	Row Score	Std Score
Individual Freq. (STDVs)							
0.5 KHz	6 to 7	7.3	1.3	6.0	0.0	5.8	-0.2
1 KHz	6 to 7	5.3	-0.7	4.6	-1.4	4.4	-1.7
2 KHz	6 to 7	6.3	0.3	5.1	-0.9	5.8	-0.2
3 KHz	7 to 10	8.0	0.3	6.5	-0.2	6.9	0.0
4 KHz	7 to 10	9.0	0.7	8.0	0.3	7.9	0.3
6 KHz	9 to 12	11.8	0.9	10.5	0.5	10.5	0.5
Mean of Standard Scores=0.0 (Marginal)**							
Averaged Freq. (STDVAs)							
0.5,1,2,3 KHz	4.5 to 6.5	5.4	0.4	4.2	-0.2	4.2	-0.2
2,3,4 KHz	5.5 to 7.5	6.7	0.6	5.2	-0.1	5.5	0.0
3,4,6 KHz	6 to 8.5	7.6	0.6	5.9	-0.1	6.1	0.0
Mean of Standard Scores=0.1 (Marginal)							
%Ws							
Percentage	20 to 30	36.3	1.6	33.7	1.4	35.9	1.6
Mean of Standard Scores=1.5 (Unacceptable)							

* Standard Score is a linear transformation of row score. The formula is:

$$stdscr=(rowscr-l)/(h-l)$$

stdscr is standard score, *rowscr* is row score, *l* is the lower limit of the row marginal range, and *h* is the upper limit of the row marginal range.

** Standard Score Marginal Range is 0 to 1. *Stdscr* below 0 is acceptable (A), between 0 and 1 is Marginal (M), above 1 is Unacceptable (U).

Table 30. Standard Scores* from %Ws, STDVs and STDVAs Procedures According to Test Comparisons of Audiometric Tests of Male Civilian Workers During 1988-1991 in the U.S. Army. (Cohort-B4, N=985)

		Test 1-2		Test 2-3		Test 3-4	
	Marginal Range	Row Score	Std Score	Row Score	Std Score	Row Score	Std Score
Individual Freq. (STDVs)							
0.5 KHz	6 to 7	7.4	1.4	6.0	0.0	5.9	-0.1
1 KHz	6 to 7	5.2	-0.8	4.7	-1.3	4.4	-1.6
2 KHz	6 to 7	6.3	0.3	5.2	-0.8	5.9	-0.1
3 KHz	7 to 10	7.8	0.3	6.6	-0.1	7.0	0.0
4 KHz	7 to 10	9.0	0.7	8.2	0.4	8.1	0.4
6 KHz	9 to 12	11.8	0.9	10.7	0.6	10.6	0.5
Mean of Standard Scores=0.0 (Marginal)**							
Averaged Freq. (STDVAs)							
0.5,1,2,3 KHz	4.5 to 6.5	5.3	0.4	4.2	-0.1	4.3	-0.1
2,3,4 KHz	5.5 to 7.5	6.6	0.5	5.3	-0.1	5.5	0.0
3,4,6 KHz	6 to 8.5	7.5	0.6	6.0	0.0	6.2	0.1
Mean of Standard Scores=0.1 (Marginal)							
%Ws							
Percentage	20 to 30	36.9	1.7	34.1	1.4	35.9	1.6
Mean of Standard Scores=1.6 (Unacceptable)							

* Standard Score is a linear transformation of row score. The formula is:

$$stdscr=(rowscr-l)/(h-l)$$

stdscr is standard score, *rowscr* is row score, *l* is the lower limit of the row marginal range, and *h* is the upper limit of the row marginal range.

** Standard Score Marginal Range is 0 to 1. *Stdscr* below 0 is acceptable (A), between 0 and 1 is Marginal (M), above 1 is Unacceptable (U).

Table 31. Standard Scores* from %Ws, STDVs and STDVAs Procedures According to Test Comparisons of Audiometric Tests of Female Civilian Workers During 1988-1991 in the U.S. Army. (Cohort-B4, N=61)

		Test 1-2		Test 2-3		Test 3-4	
	Marginal Range	Row Score	Std Score	Row Score	Std Score	Row Score	Std Score
Individual Freq. (STDVs)							
0.5 KHz	6 to 7	7.0	1.0	5.9	-0.1	5.2	-0.8
1 KHz	6 to 7	6.3	0.3	3.7	-2.3	3.4	-2.6
2 KHz	6 to 7	6.2	0.2	4.0	-2.0	3.8	-2.2
3 KHz	7 to 10	9.6	0.9	5.0	-0.7	4.8	-0.7
4 KHz	7 to 10	9.8	0.9	5.1	-0.6	5.1	-0.6
6 KHz	9 to 12	12.9	1.3	7.0	-0.7	8.7	-0.1
Mean of Standard Scores=-0.5 (Acceptable)**							
Averaged Freq. (STDVAs)							
0.5,1,2,3 KHz	4.5 to 6.5	6.1	0.8	3.5	-0.5	3.1	-0.7
2,3,4 KHz	5.5 to 7.5	7.7	1.1	3.8	-0.8	3.7	-0.9
3,4,6 KHz	6 to 8.5	9.7	1.5	3.9	-0.9	4.4	-0.6
Mean of Standard Scores=-0.1 (Acceptable)							
%Ws							
Percentage	20 to 30	27.9	0.8	26.2	0.6	36.1	1.6
Mean of Standard Scores=1.0 (Marginal)							

* Standard Score is a linear transformation of row score. The formula is:

$$stdscr=(rowscr-l)/(h-l)$$

stdscr is standard score, *rowscr* is row score, *l* is the lower limit of the row marginal range, and *h* is the upper limit of the row marginal range.

** Standard Score Marginal Range is 0 to 1. *Stdscr* below 0 is acceptable (A), between 0 and 1 is Marginal (M), above 1 is Unacceptable (U).

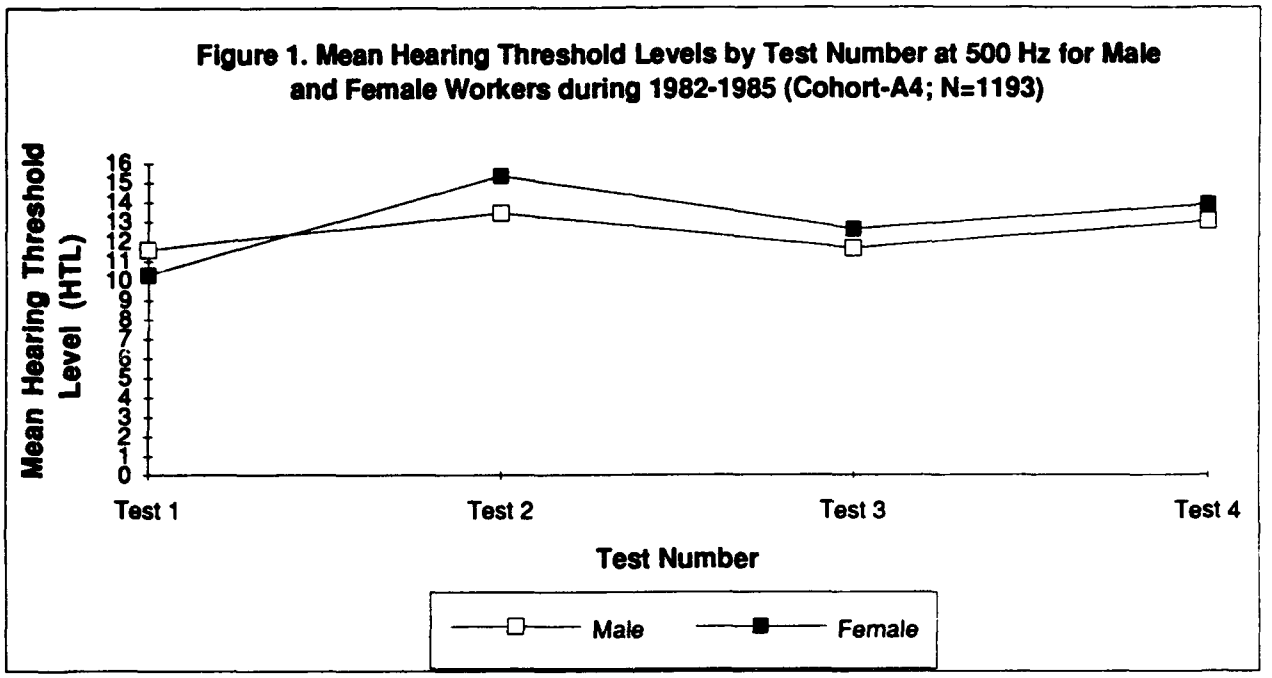


Figure 1. Mean Hearing Threshold Levels by Test Number at 500 Hz for Male and Female Workers during 1982-1985 (Cohort-A4; N=1193)
Mean Hearing Threshold Level (HTL)
0
Test 1
Test 2
Test 3
Test 4
Test Number
Male
Female

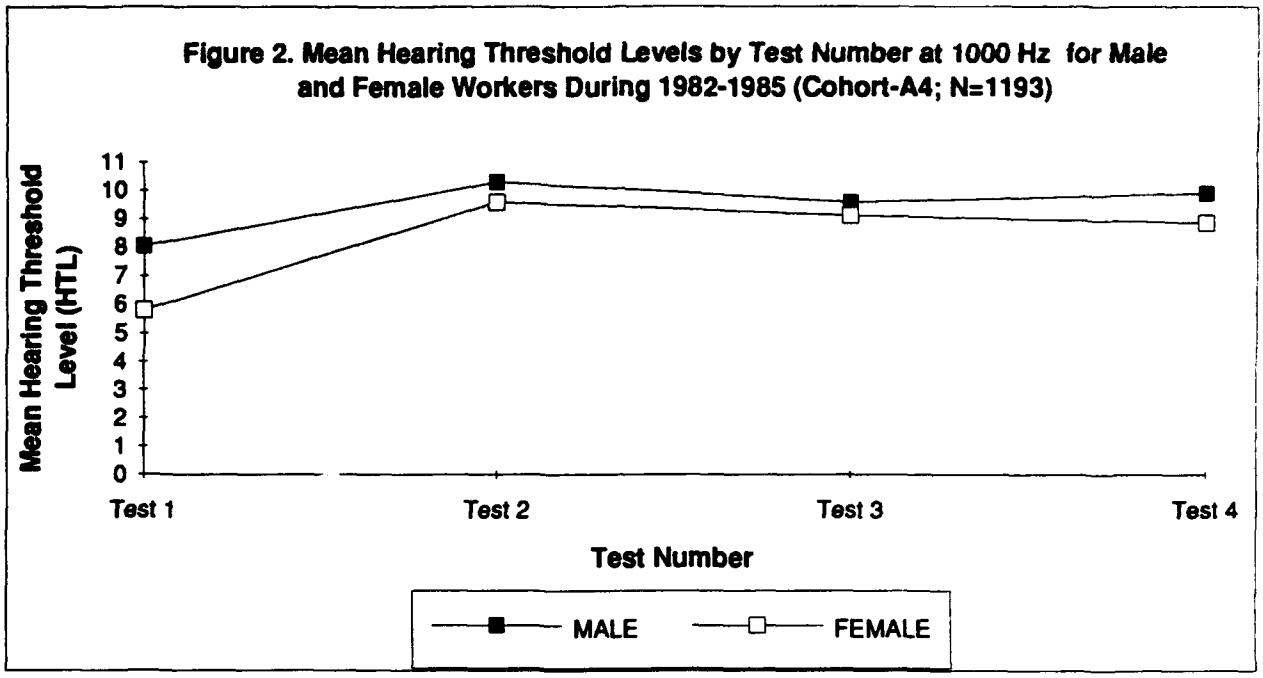


Figure 2. Mean Hearing Threshold Levels by Test Number at 1000 Hz for Male and Female Workers During 1982-1985 (Cohort-A4; N=1193)
Mean Hearing Threshold Level (HTL)
11
10
9
8
7
6
5
4
3
2
1
0
Test 1
Test 2
Test 3
Test 4
Test Number
MALE
FEMALE

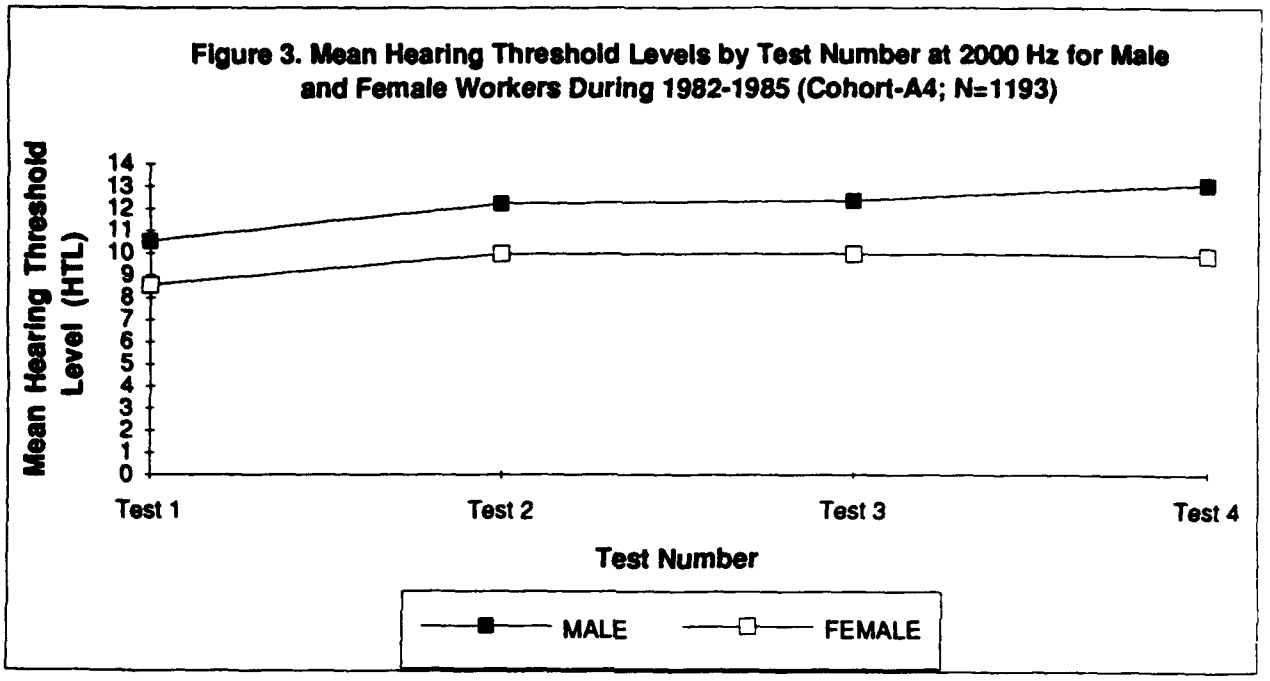


Figure 3. Mean Hearing Threshold Levels by Test Number at 2000 Hz for Male and Female Workers During 1982-1985 (Cohort-A4; N=1193)
Mean Hearing Threshold Level (HTL)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Test 1
Test 2
Test 3
Test 4
Test Number
MALE
FEMALE

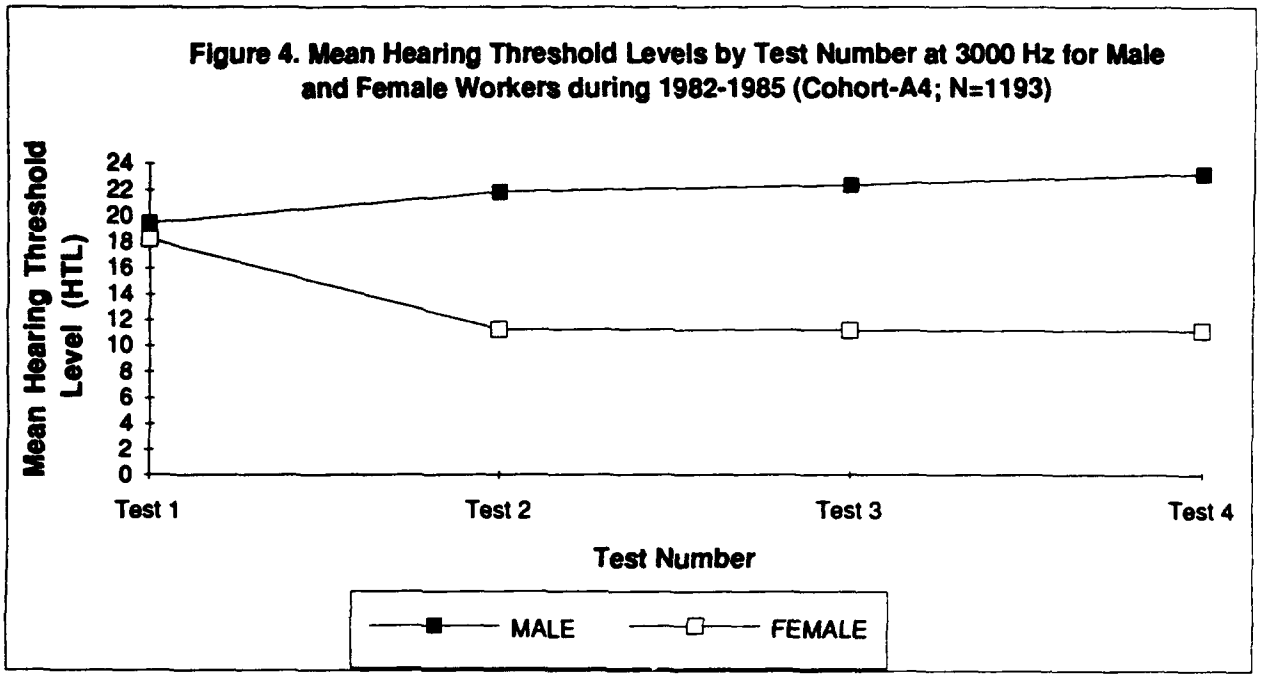


Figure 4. Mean Hearing Threshold Levels by Test Number at 3000 Hz for Male and Female Workers during 1982-1985 (Cohort-A4; N=1193)
Mean Hearing Threshold Level (HTL)
24
22
20
18
16
14
12
10
8
6
4
2
0
Test 1
Test 2
Test 3
Test 4
Test Number
MALE
FEMALE

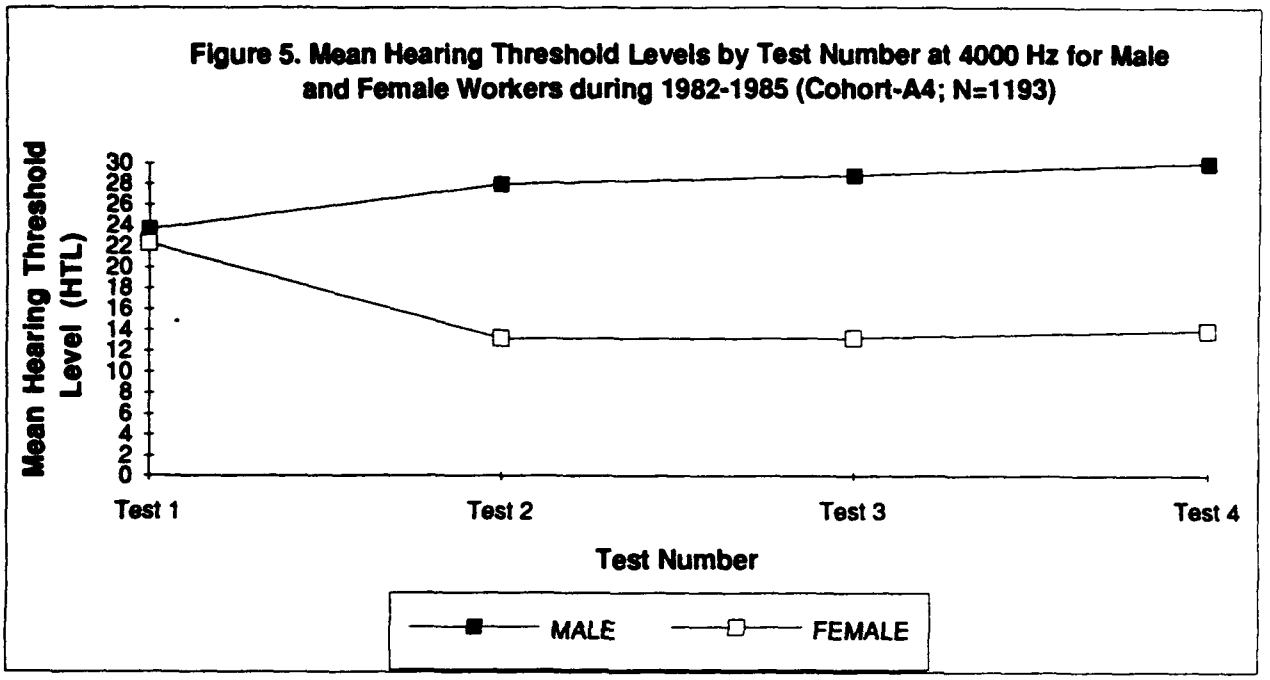
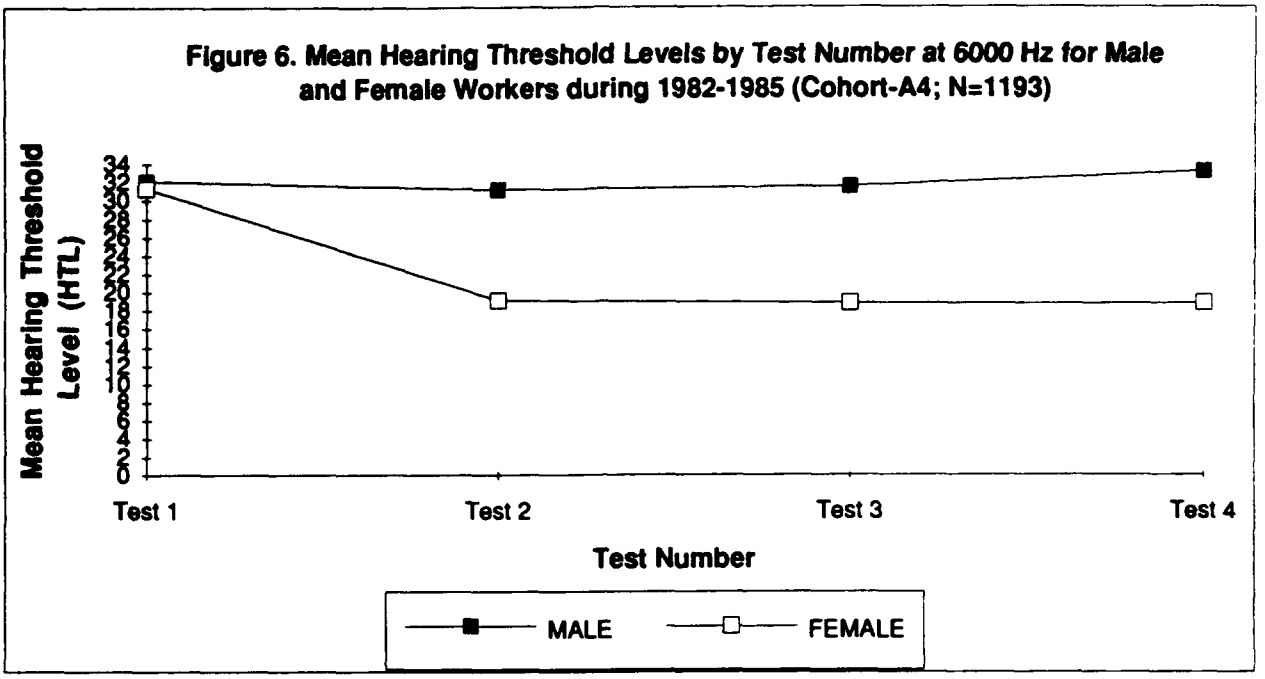


Figure 5. Mean Hearing Threshold Levels by Test Number at 4000 Hz for Male and Female Workers during 1982-1985 (Cohort-A4; N=1193)
Mean Hearing Threshold Level (HTL)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Test 1
Test 2
Test 3
Test 4
Test Number
MALE
FEMALE

Figure 6. Mean Hearing Threshold Levels by Test Number at 6000 Hz for Male and Female Workers during 1982-1985 (Cohort-A4; N=1193)



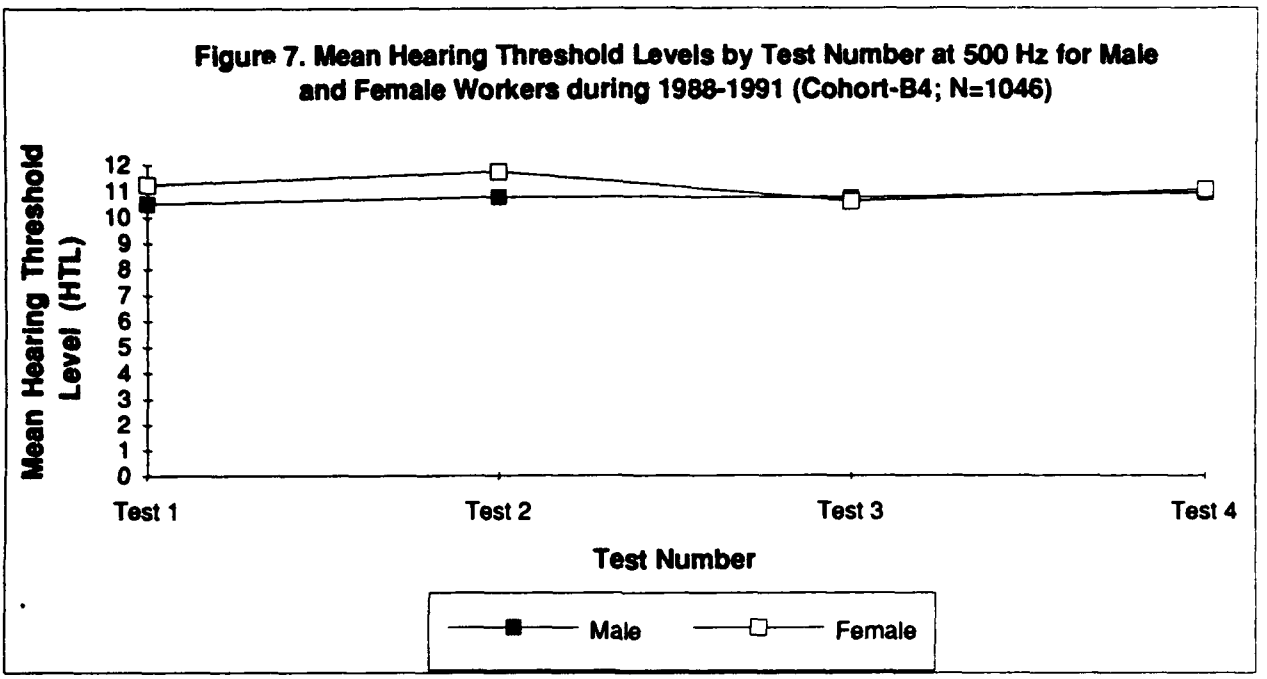


Figure 7. Mean Hearing Threshold Levels by Test Number at 500 Hz for Male and Female Workers during 1988-1991 (Cohort-B4; N=1046)
Mean Hearing Threshold Level (HTL)
12
11
10
9
8
7
6
5
4
3
2
1
0
Test 1
Test 2
Test 3
Test 4
Test Number
Male
Female

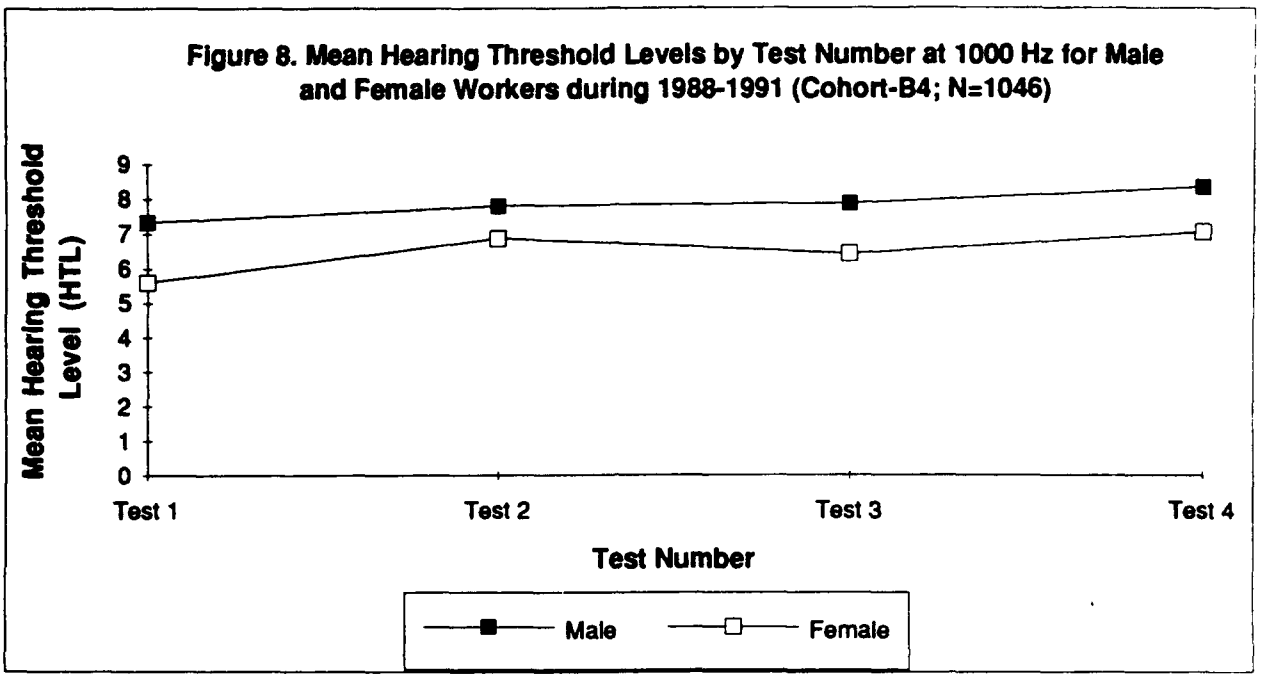


Figure 8. Mean Hearing Threshold Levels by Test Number at 1000 Hz for Male and Female Workers during 1988-1991 (Cohort-B4; N=1046)
Mean Hearing Threshold Level (HTL)
9
8
7
6
5
4
3
2
1
0
Test 1
Test 2
Test 3
Test 4
Test Number
Male
Female

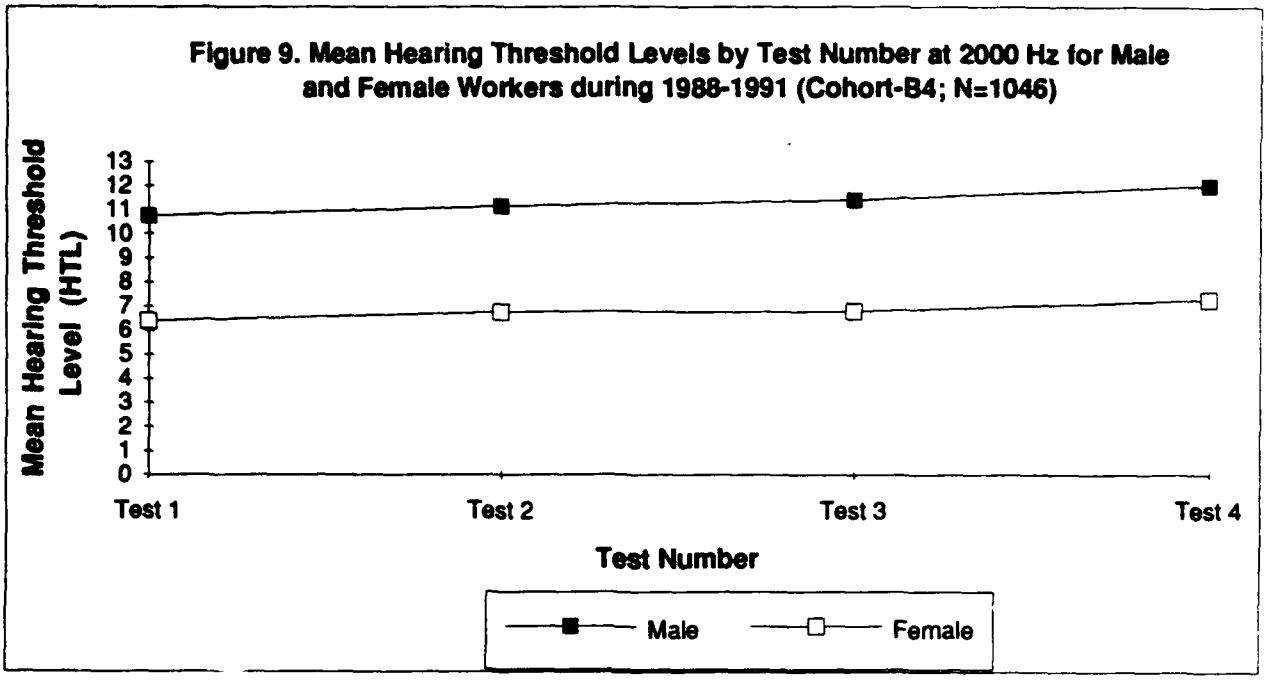


Figure 9. Mean Hearing Threshold Levels by Test Number at 2000 Hz for Male and Female Workers during 1988-1991 (Cohort-B4; N=1046)
Mean Hearing Threshold Level (HTL)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Test 1
Test 2
Test 3
Test 4
Test Number
Male
Female

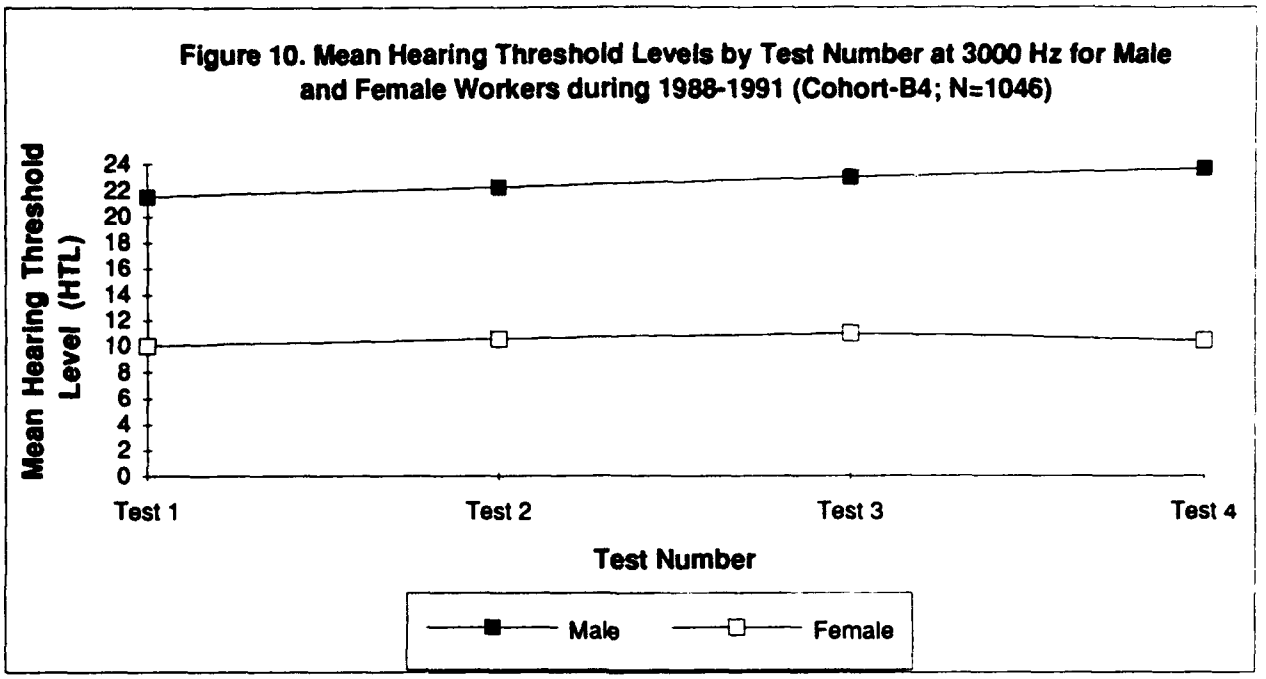


Figure 10. Mean Hearing Threshold Levels by Test Number at 3000 Hz for Male and Female Workers during 1988-1991 (Cohort-B4; N=1046)
Mean Hearing Threshold Level (HTL)
24
22
20
18
16
14
12
10
8
6
4
2
0
Test 1
Test 2
Test 3
Test 4
Test Number
Male
Female

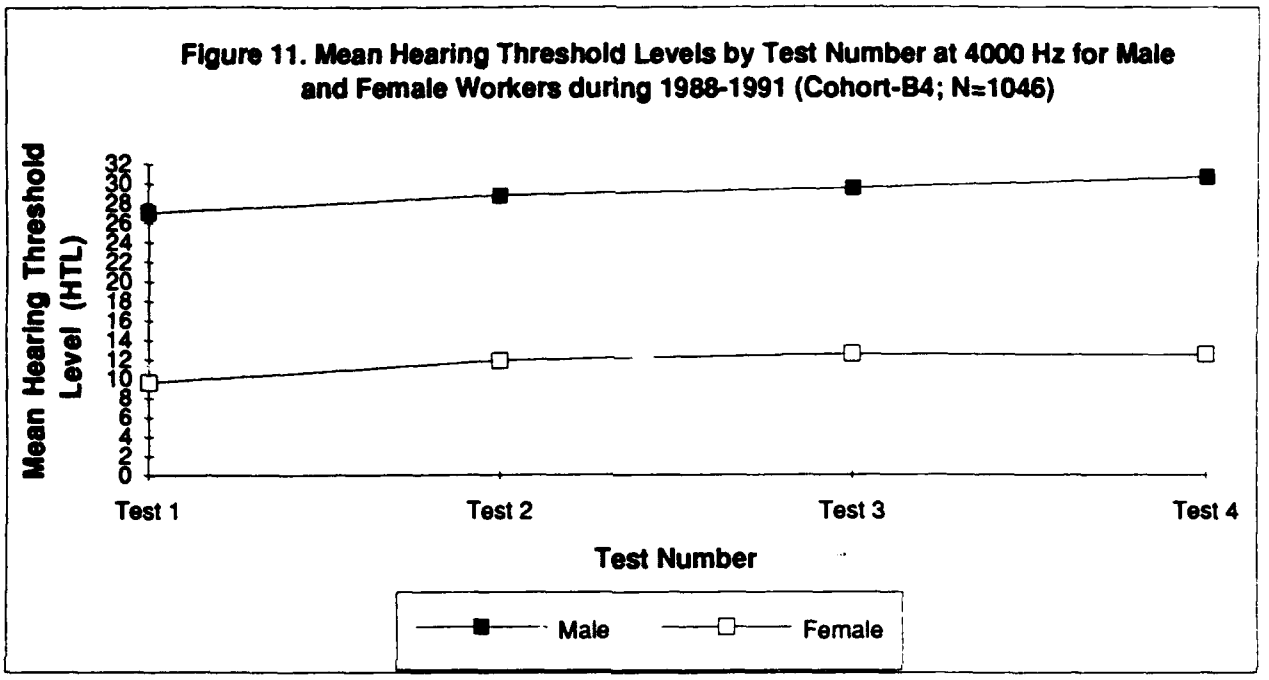


Figure 11. Mean Hearing Threshold Levels by Test Number at 4000 Hz for Male and Female Workers during 1988-1991 (Cohort-B4; N=1046)
Mean Hearing Threshold Level (HTL)
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Test 1
Test 2
Test 3
Test 4
Test Number
Male
Female

Figure 12. Mean Hearing Threshold Levels by Test Number at 6000 Hz for Male and Female Workers during 1988-1991 (Cohort-B4; N=1046)

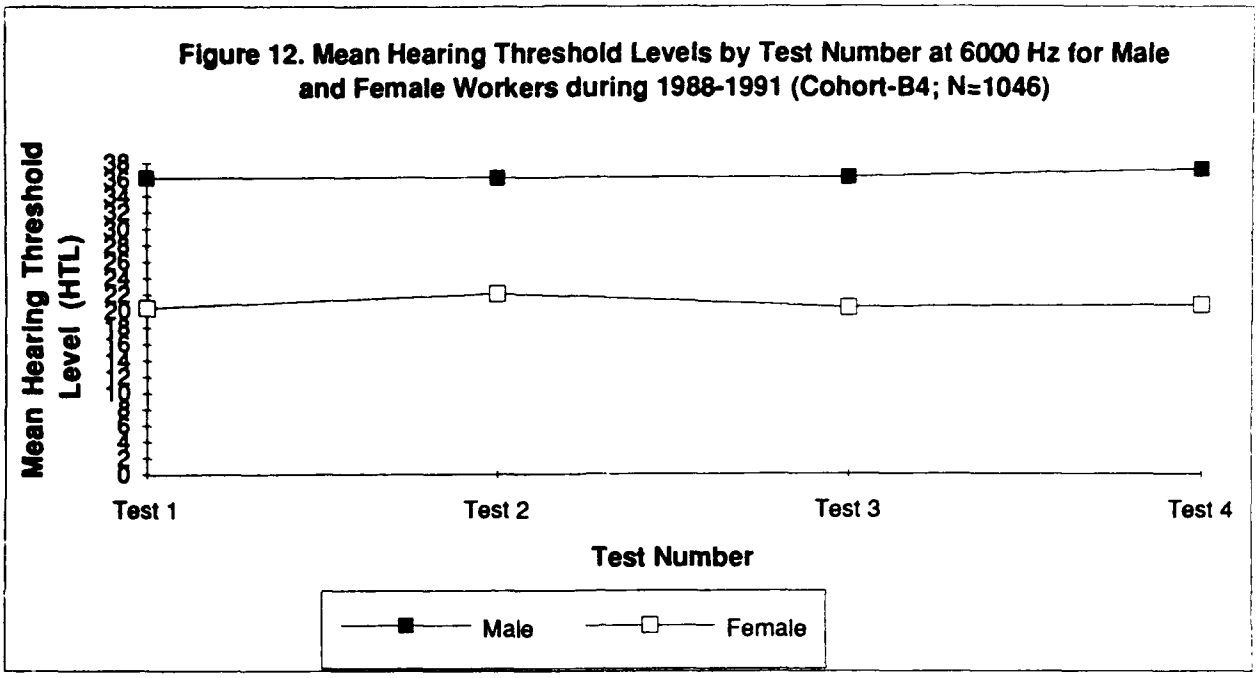


Figure 13. Mean Hearing Threshold Levels by Test Number for Male Workers during 1982-1985 (Cohort-A4; N=1094)

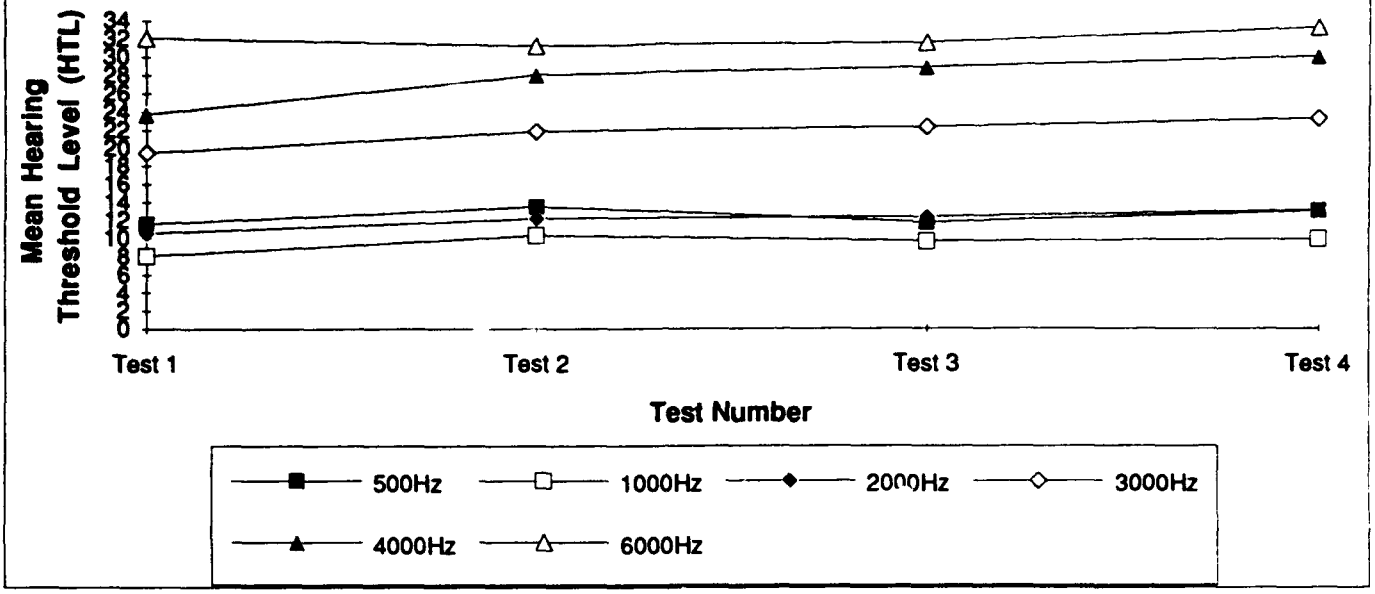


Figure 14. Mean Hearing Threshold Levels by Test Nubmer for Female Workers during 1982-1985 (Cohort-A4; N=99)

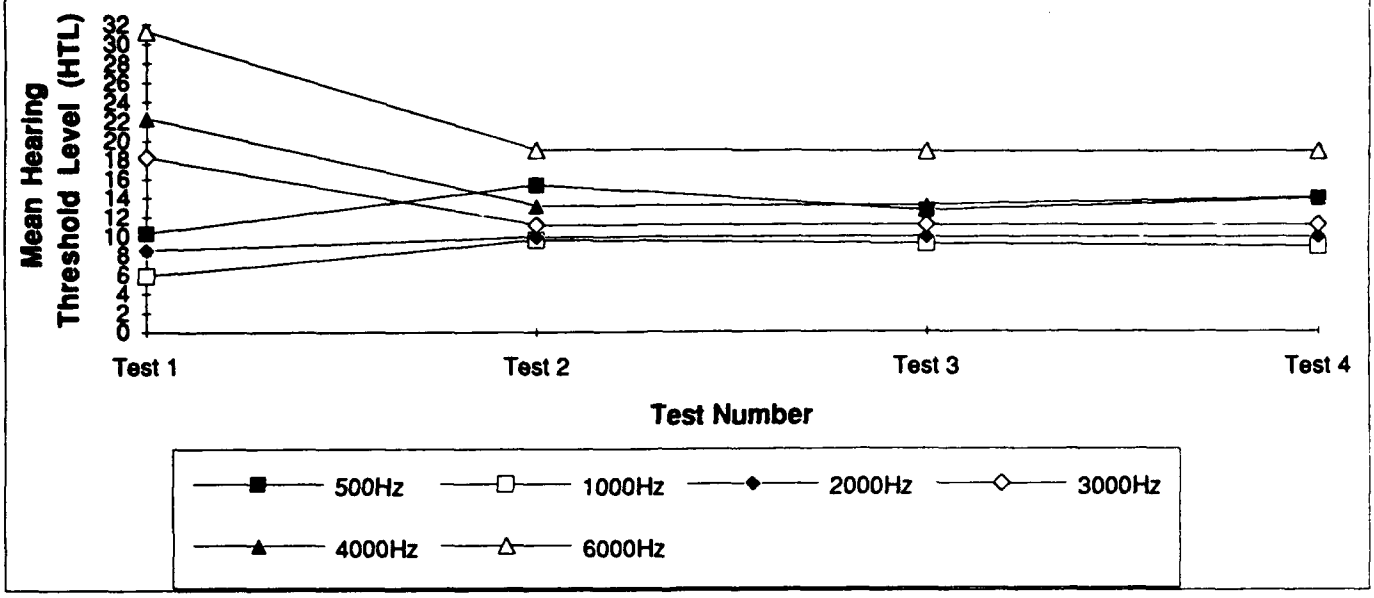


Figure 15. Mean Hearing Threshold Levels by Test Number for Male Workers during 1982-1989 (Cohort-A8; N=246)

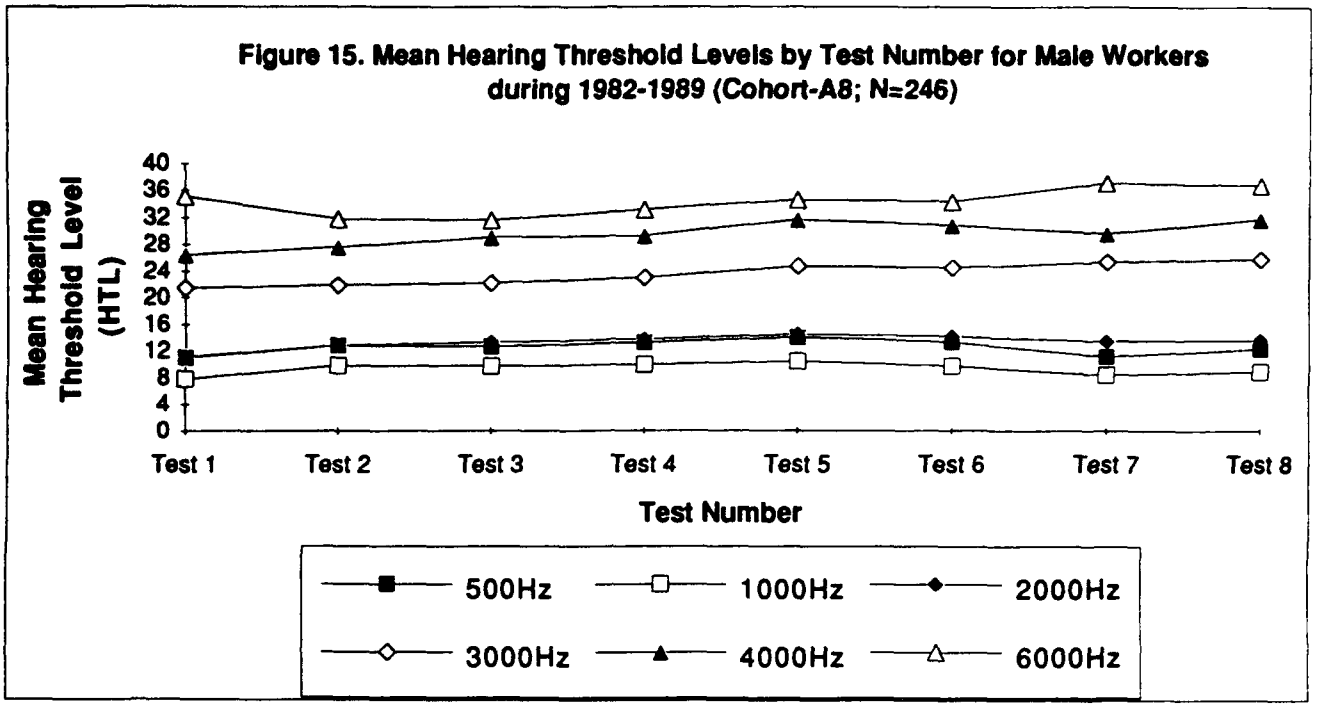


Figure 16. Mean Hearing Threshold Levels by Test Number for Male Workers during 1988-1991 (Cohort-B4; N=985)

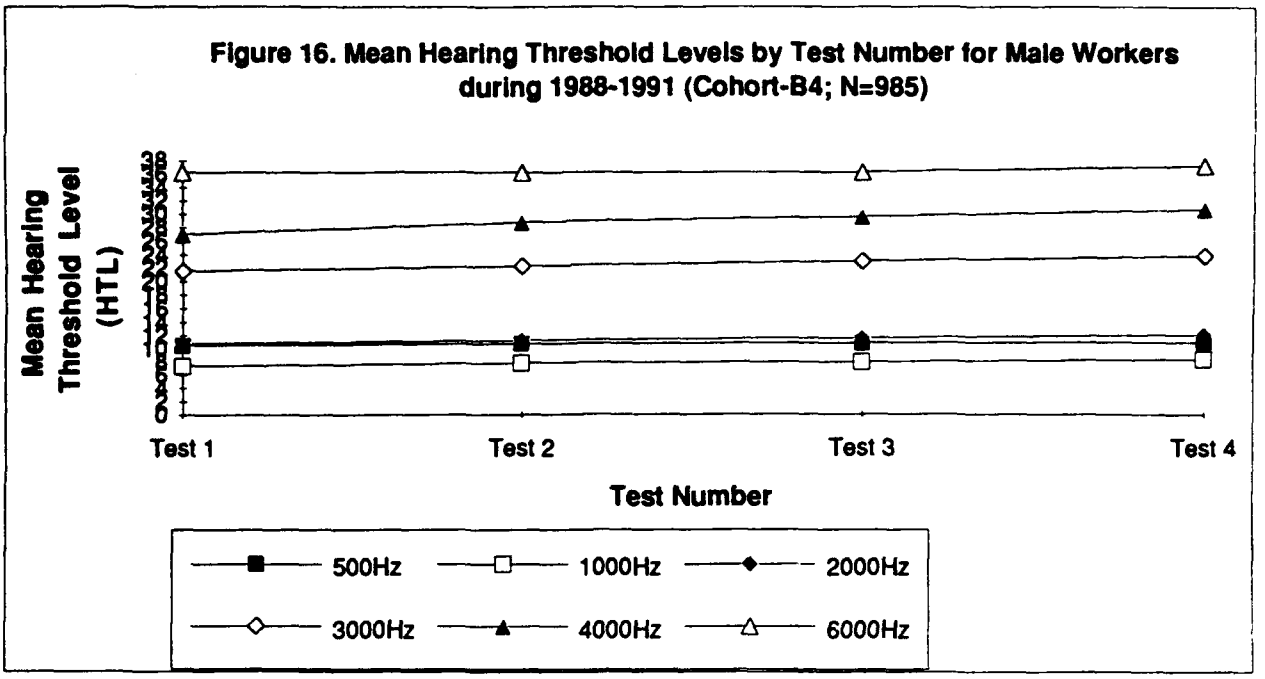
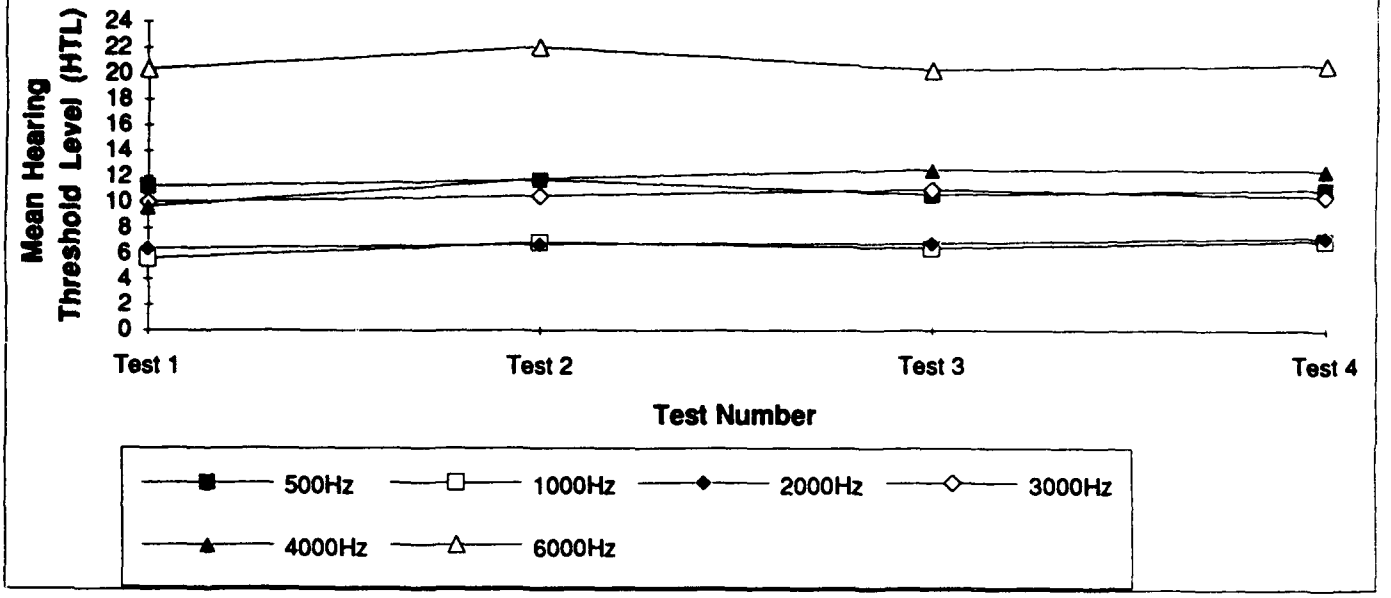


Figure 17. Mean Hearing Threshold Levels by Test Number for Female Workers during 1988-1991 (Cohort-B4; N=61)



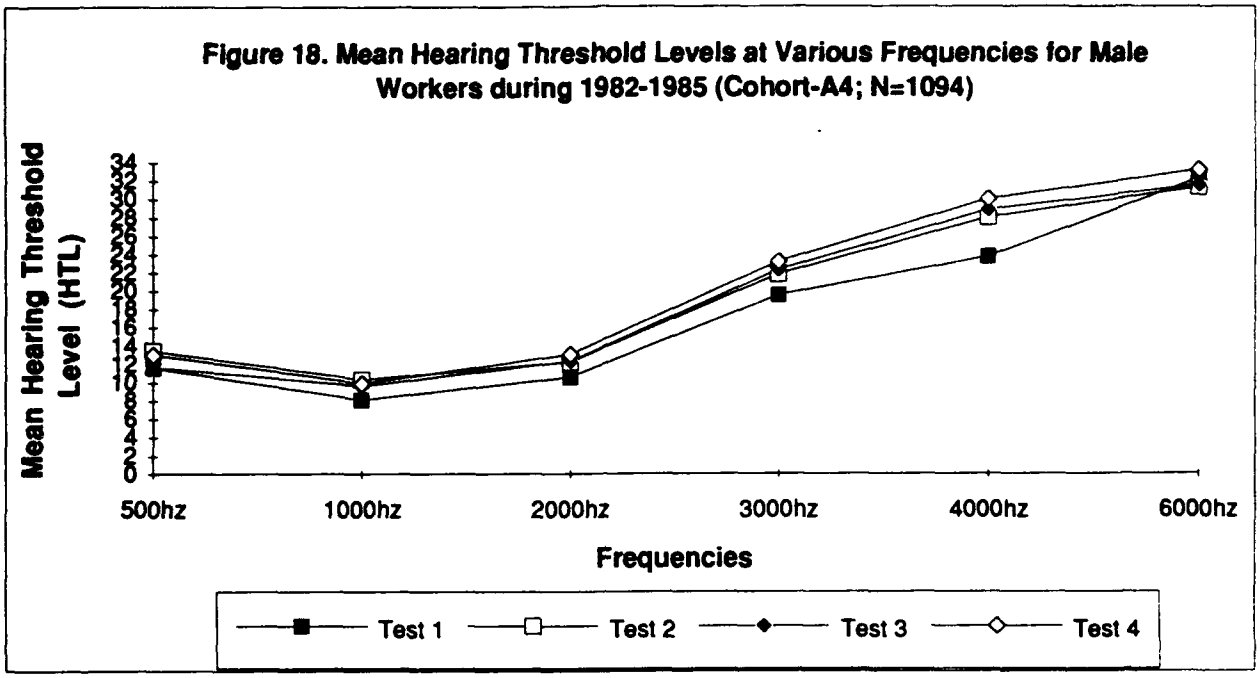


Figure 18. Mean Hearing Threshold Levels at Various Frequencies for Male Workers during 1982-1985 (Cohort-A4; N=1094)
Mean Hearing Threshold Level (HTL)
500hz
1000hz
2000hz
3000hz
4000hz
6000hz
Frequencies
Test 1
Test 2
Test 3
Test 4

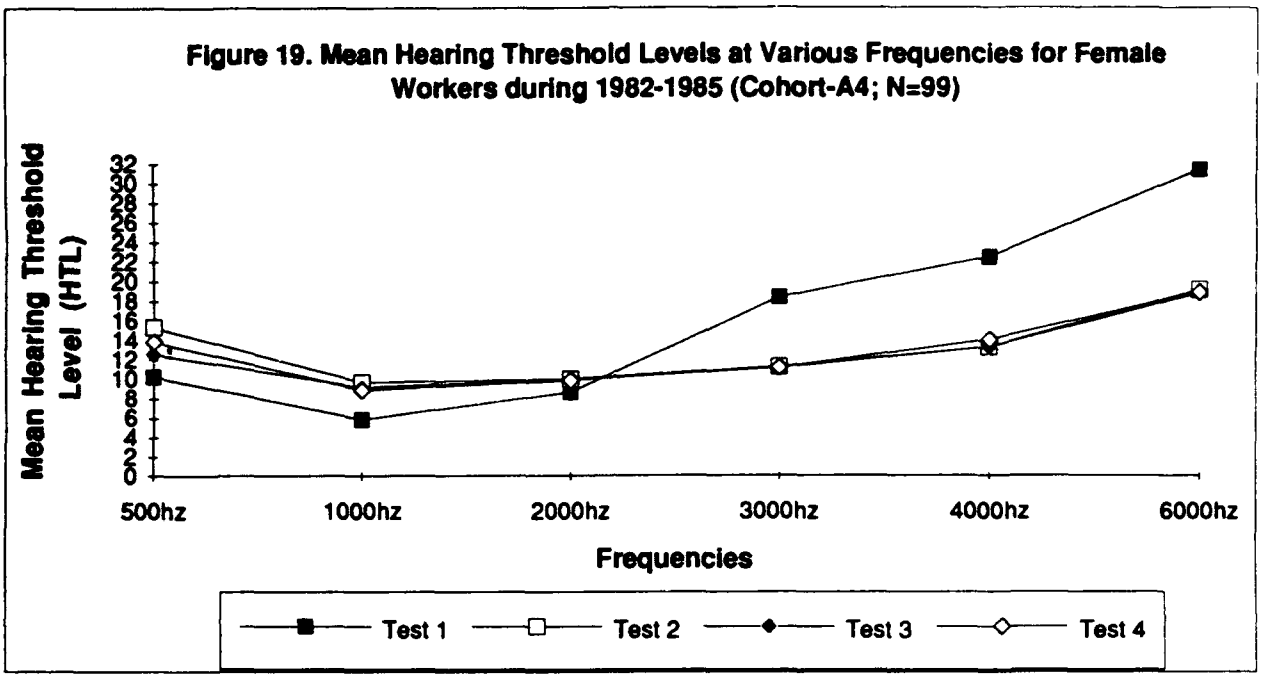
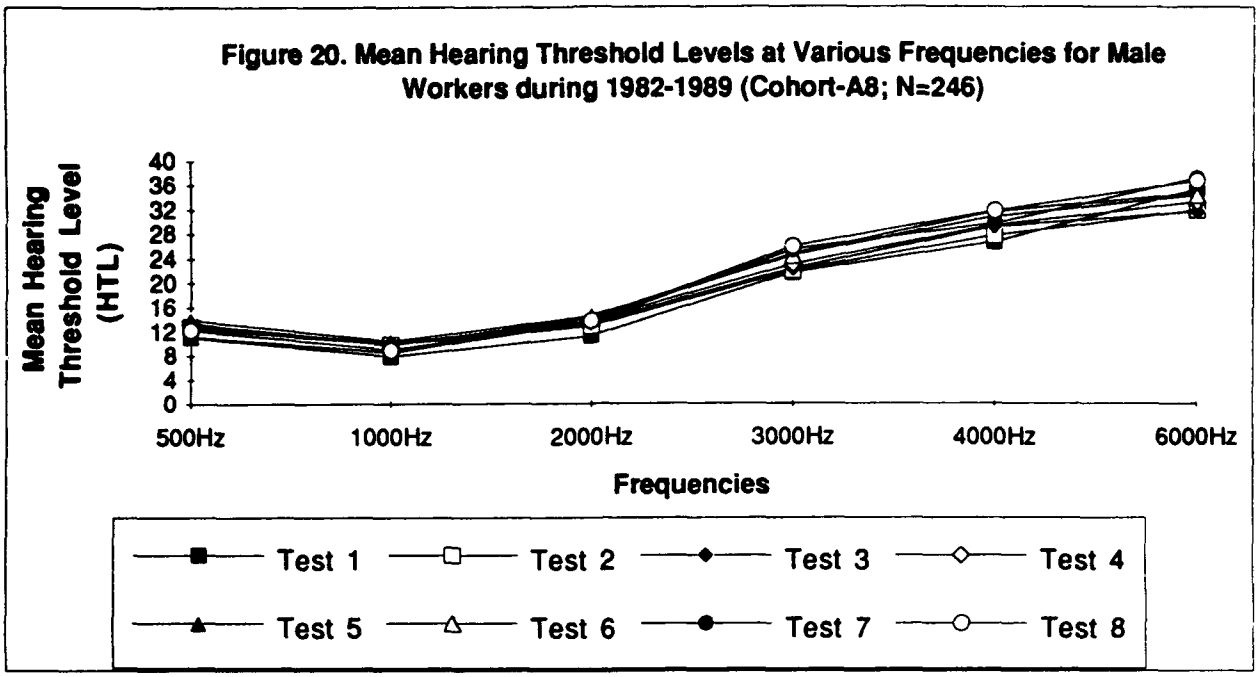


Figure 19. Mean Hearing Threshold Levels at Various Frequencies for Female Workers during 1982-1985 (Cohort-A4; N=99)
Mean Hearing Threshold Level (HTL)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
500hz
1000hz
2000hz
3000hz
4000hz
6000hz
Frequencies
Test 1
Test 2
Test 3
Test 4

Figure 20. Mean Hearing Threshold Levels at Various Frequencies for Male Workers during 1982-1989 (Cohort-A8; N=246)



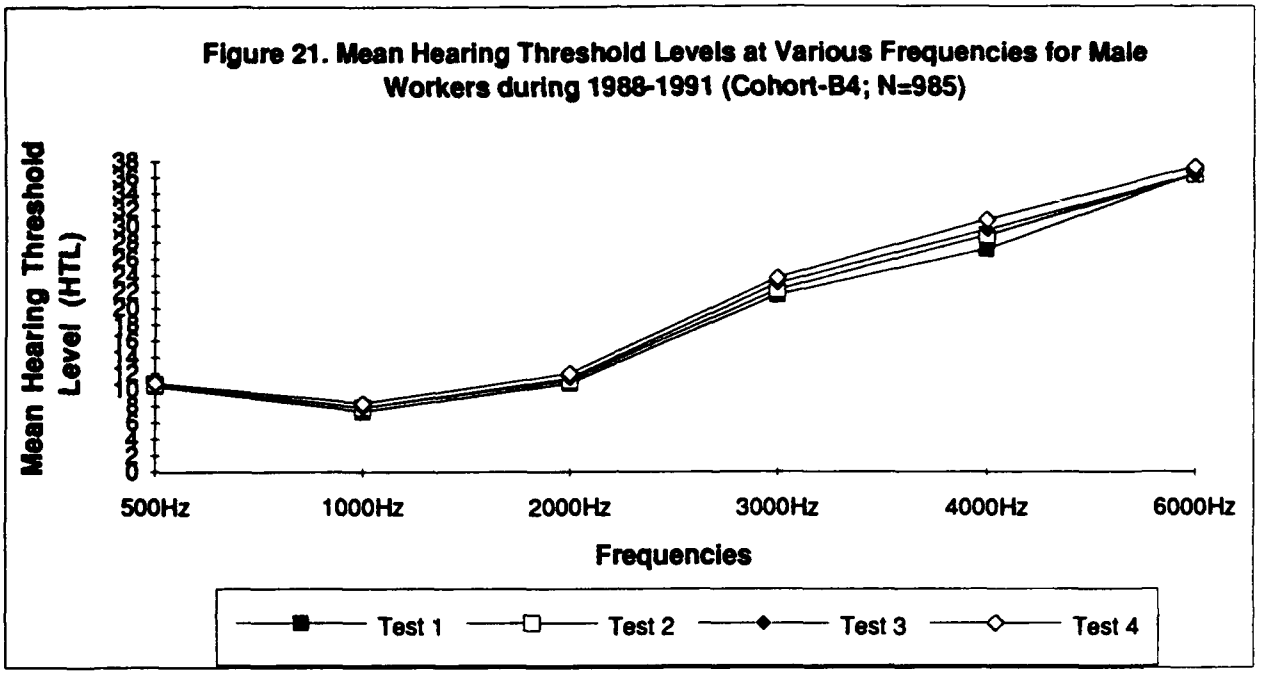


Figure 21. Mean Hearing Threshold Levels at Various Frequencies for Male Workers during 1988-1991 (Cohort-B4; N=985)
Mean Hearing Threshold Level (HTL)
500Hz
1000Hz
2000Hz
3000Hz
4000Hz
6000Hz
Frequencies
Test 1
Test 2
Test 3
Test 4

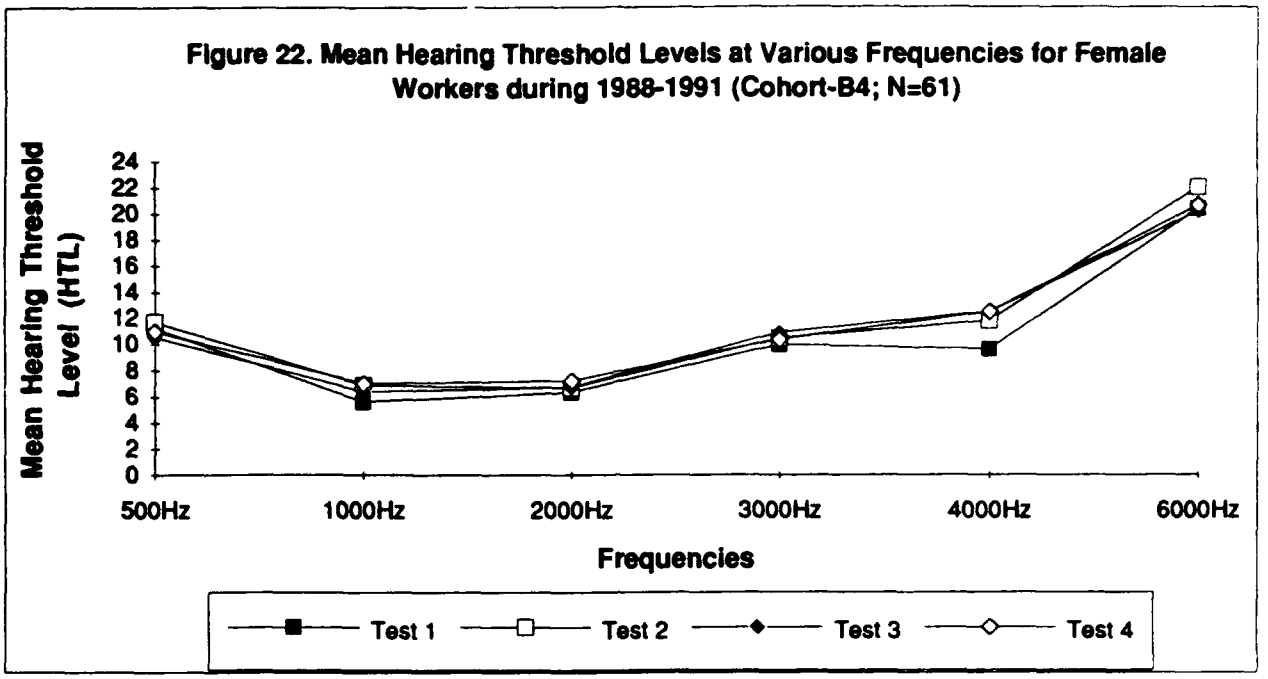


Figure 22. Mean Hearing Threshold Levels at Various Frequencies for Female Workers during 1988-1991 (Cohort-B4; N=61)
Mean Hearing Threshold Level (HTL)
24
22
20
18
16
14
12
10
8
6
4
2
0
500Hz
1000Hz
2000Hz
3000Hz
4000Hz
6000Hz
Frequencies
Test 1
Test 2
Test 3
Test 4